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MISSILE AND SPACE SYSTEMS RELIABILITY VS COST TRADE-OFF STUDY

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Boeing Aerospace Company

Roger C. Hall, Timothy G. Milliren and Robert C. Schneider

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This report consisting of a user's guide (Part I) and back-up data (Part II), was developed to provide reliability program/task cost guidelines to DoD program reliability managers and monitors. The primary use of the guidelines is for assistance in tailoring task provisions of MIL-STD-785 and MIL-STD-1543 (USAF) as applied to space and missile systems. Displayed data includes program/task cost statistics developed as a function of program/system phase and other significant characteristics. The study

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data base includes program/task cost statistics developed as a function of a program/system phase and other significant characteristics. The study data base includes program/task costs derived from 13 space/missile programs and results from a program/system characteristic cost impact survey. These data along with the associated analyses are summarized in Part II of the study.

A

SUMMARY

This report, consisting of a user's guide (Part I) and back-up data (Part II), was developed to provide reliability program/task cost guidelines to DoD program reliability managers and monitors. The primary use of the guidelines is for assistance in tailoring the task provisions of MIL-STD-785 and MIL-STD-1543 (USAF) as applied to space and missile systems.

Data developed and incorporated in the guidelines includes program/task cost statistics derived from study and analysis of thirteen different missile and space programs. In addition, results of a survey on the impact of program/system characteristics on program/task costs and on various tailoring options are included.

Reliability program/task cost statistics are presented in terms of manhours, percentage of engineering budget and percentage of reliability program budget. The percentage figures are normalized to annual expenditures to provide annual effort intensity measures. Statistics given include averages and measures of deviation for various program types and phases. Guidelines are provided for the application of these statistics and associated program/system descriptive data to the problem of scoping and tailoring program

reliability efforts. Tailoring considerations, based on the combined effects of task cost and task effectiveness, are also included as part of the guidelines material. Finally, supplementary material i.e., ground rules, definitions and descriptive data, is presented to properly qualify and detail the study results.

PREFACE

This report was prepared by Logistics Design Support, Product Support Organization of Boeing Aerospace Company, Seattle, Washington. The study effort was conducted under Contract No. F30602-81-C-0195 with Rome Air Development Center, Griffiss Air Force Base, New York. Mr. William J. Bocchi (RBES) was the RADC Project Engineer. The contract period of performance was twelve (12) months, starting on 27 October 1981.

Logistics Design Support technical leader was Robert C. Schneider. Principal program analysts were Timothy G. Milliren and Roger C. Hall.

Acknowledgement is made and appreciation is expressed to the many Boeing Aerospace Company program reliability managers and engineers who supplied technical and cost data, participated in the cost impact survey and provided guidance and consultation.

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AGM	Air to Ground Missile
CDR	Critical Design Review
CFE	Contractor Furnished Equipment
CONCEPT	Conceptual Phase
D&V	Development and Validation (Also See VALID)
DEV/GROWTH TEST	Development and Growth Test (Also See RDGT)
ENG	Engineering
ESS	Environmental Stress Screening (Also See PRVT)
FLT SEG	Flight Segment
FMECA	Failure Modes, Effects, and Criticality Analysis
FRACAS	Failure Reporting, Analysis, and Corrective Action System
FRB	Failure Review Board
FSED	Full Scale Engineering Development
GAM	Ground to Air Missile
GND SEG	Ground Segment
LSAP	Logistics Support Analysis Program
LSAR	Logistics Support Analysis Report

GLOSSARY OF ACRONYMS AND ABBREVIATIONS (CONT'D)

MM	Manmonth Average or Job Hours in One Month (Approx. 153 Hours)
MM/YR	Manmonths per Year; a Measure of Intensity or Level of Effort
PA	Procuring Activity (Including Program/Project Offices)
PDR	Preliminary Design Review
% ENG BUDGET	Percent of Engineering Budget: A measure of a program expenditure expressed as a percentage of the total or annual engineering budget for the program
PRAT	Production Reliability Acceptance Test
PROD	Production
PRVT	Production Reliability Verification Test (Also See ESS)
RDGT	Reliability Development/Growth Test
RQT	Reliability Qualification Test
SCA	Sneak Circuit Analysis

GLOSSARY OF ACRONYMS AND ABBREVIATIONS (CONT'D)

SOA	State of the Art
SOW	Statement of Work
TAAF	Test Analyze and Fix
TOL ANAL	Tolerance Analysis (Also Referred to as Electronics Parts/Circuit Tolerance Analysis)
VALID	Validation

1.0 INTRODUCTION

1.1 A NEED FOR RELIABILITY COST GUIDELINES

Ideally, the reliability task provisions of MIL-STD-785 or MIL-STD-1543 (USAF) could be tailored to a particular program or system without critical reference to task costs. Rationale for the tailoring process would be based on selecting and implementing only those tasks to the extent and level of detail that made sense for a particular program or system. The features of a particular program/system like development phase, or system development status would dictate the tailoring process.

Since ideal conditions are the exception rather than the rule, reliability managers or monitors must be prepared to deal with budget constraints, biases and other factors which can significantly affect their reliability programs. Each of these factors, especially that of budget, must be dealt with properly to avoid either short sighted planning leading ultimately to higher costs or to avoid inefficient use of resources which yield merely an illusion of reliability assurance.

The following set of reliability program/task cost guidelines have been developed to assist the program reliability manager/monitor in the job of tailoring a reliability program. First, the guidelines provide a general picture of reliability program and task costs for a typical space or missile system. These more general cost estimates satisfy the two-fold need for baseline criteria and for a standard of credibility. Second, the guidelines provide cost data, costing methods, and task effectiveness criteria useful in conducting trade studies in support of tailoring decisions. Together, the guidelines provide a proven basis for judging the cost and effectiveness impact of tailoring decisions for either a selected task or a total reliability program.

The following figure provides a simplified flow diagram of the task tailoring process. Shown are the process essentials and how these essentials flow and interface in the development of an effective reliability program.

1.2 Guideline Material Arrangement

Material in the guidelines is grouped and sequenced as shown in Table 1-1. For those users desiring only "broad brush" information, an overview is provided in Section 2.0. Section 3.0 (covering

DEVELOPMENT OF A COST EFFECTIVE RELIABILITY PROGRAM

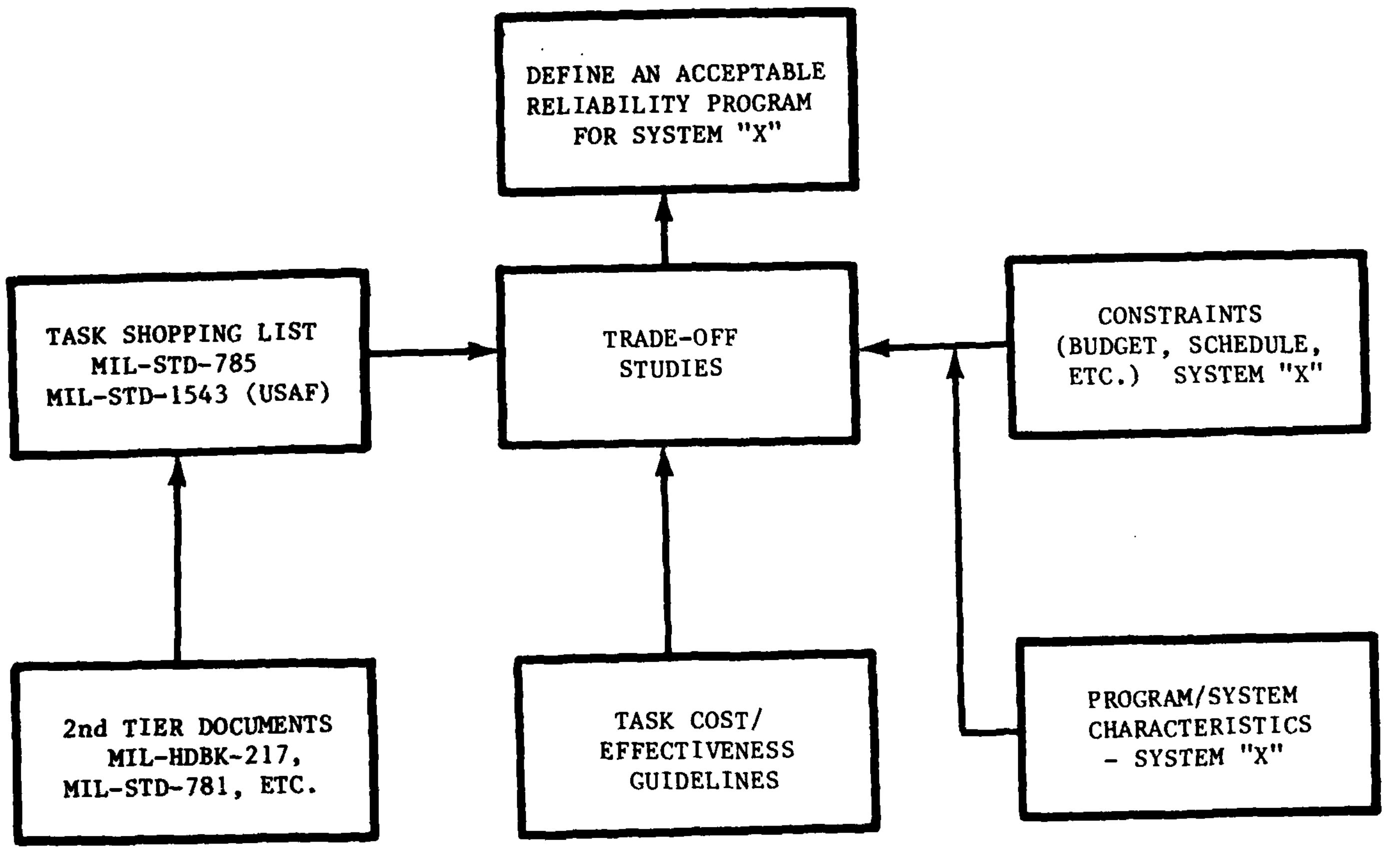


TABLE 1-1 - GUIDELINE MATERIAL ARRANGEMENT

TOPIC	SECTION	SUMMARY
OVERVIEW	2.0	Provides historical perspective to cost data, identifies cost drivers and discusses program effectiveness.
GUIDELINE APPLICABILITY	3.1	Qualifies guideline use by system type, contractor level, program structure and reliability program type.
DATA DEVELOPMENT	3.2	Describes cost measures and their development and task cost categories.
COST ESTIMATION	3.3	Provides data, procedures and examples for estimating reliability task and program costs.
TAILORING	4.0	Lists some fundamentals of tailoring plus comments on tailoring of specific tasks.
APPENDICES	A	Details the data base used in developing the guidelines.
	B	Shows development of cost estimation regression equations.
	C	Summarized MIL-STD-785B task descriptions.

"step-by-step" cost estimation procedures) and Section 4.0 (dealing with tailoring concepts) are for specific use by reliability program managers and monitors. Finally, a series of appendices is provided for those desiring an in-depth view of the underlying data base and analysis methods.

2.0 OVERVIEW

2.1 Historical Perspective

It is not intended that the statistical cost data presented in this Overview Section be used for reliability program and task cost estimation purposes. The data have not been "scrubbed", "purged" or otherwise altered to reflect the many qualifications and nuances required of any in-depth analysis. Presentation of the data is made to provide the guide user a general picture of what, on the basis of historical cost data gathered from a spectrum of space and missile programs, constitutes average reliability program expenditures. The cost guideline data and associated application procedures for use in estimating baseline and baseline variant reliability program and task expenditures are presented in Section 3.0.

Raw cost data was derived from a study of reliability program and task costs on thirteen missile and space system programs. These programs, described briefly in Table 2-1, cover the major phases (Concept Phase excluded) of development and production and range in scope from large missile (ICBM) to small spacecraft (Satellite).

TABLE 2-1 - PROGRAM AND TASK COST DATA SOURCES

DESIGNATION	PROGRAM TYPE	PHASE	SAMPLE INTERVAL		SPONSORING AGENCY	GOVERNING MILITARY STANDARD
			MONTHS	YRS.		
A	MISSILE/SPACE	VALID	66	5.5	U.S. ARMY	MIL-STD-785A
B	SMALL MISSILE	VALID	30	2.5	USAF	MIL-STD-785A
C	MISSILE/TORPEDO	VALID	39	3.25	U.S. NAVY	MIL-STD-785B
D	MISSILE/SPACE	VALID	48	4.0	USAF	MIL-STD-1543
E	MISSILE (AGM)	FSED	75	6.25	USAF	MIL-STD-785A
F	MISSILE (AGM)	FSED	27	2.25	USAF	MIL-STD-785A
G	LARGE SPACE	FSED	60	5.0	USAF/NASA	MIL-STD-1543
H	ICBM (GND.SEG.)	FSED	60	5.0	USAF	MIL-STD-1543
I	MISSILE (AGM)	PROD	36	3.0	USAF	MIL-STD-785A
J	ICBM (FLT.SEG.)	PROD	48	4.0	USAF	MIL-STD-785A
K	MISSILE (GAM)	PROD	39	3.25	U.S. ARMY	QR800 SERIES
L	SMALL SPACE	DEV/PROD	51	4.25	USAF	MIL-STD-785A
M	SMALL SPACE	DEV/PROD	30	2.5	USAF	MIL-STD-785A

Summaries of the reliability expenditures on the above programs, for both individual and average cases, are shown in Tables 2-2 through 2-7. Expenditures are given in terms of manmonths per year (MM/YR), percentage of engineering budget and percentage of reliability budget to afford easy reference to several common standards. Listed tasks and task combinations are defined in Section 3.2.

Table 2-2 presents, on an individual program basis, a comparison between engineering and reliability program MM/YR expenditures. The engineering program expenditures are ordered, from highest (Program E) to lowest (Program L). This same program sequence (E, F, H, G,...,L) is used for the reliability program expenditures to give visibility to the correlation between engineering and reliability efforts. The MM/YR cost measure indicates the average program intensity level over the interval during which cost statistics were gathered.

A similar comparison between engineering and reliability program expenditures, but as a function of program phase and program type, is provided in Table 2-3. Here, the MM/YR expenditures reflect the average of the programs fitting the category descriptions. Again, the high correlation between engineering and reliability program efforts is evident. Reliability program efforts on major programs

TABLE 2-2 - ENGINEERING AND RELIABILITY PROGRAM EXPENDITURES - MM/YR

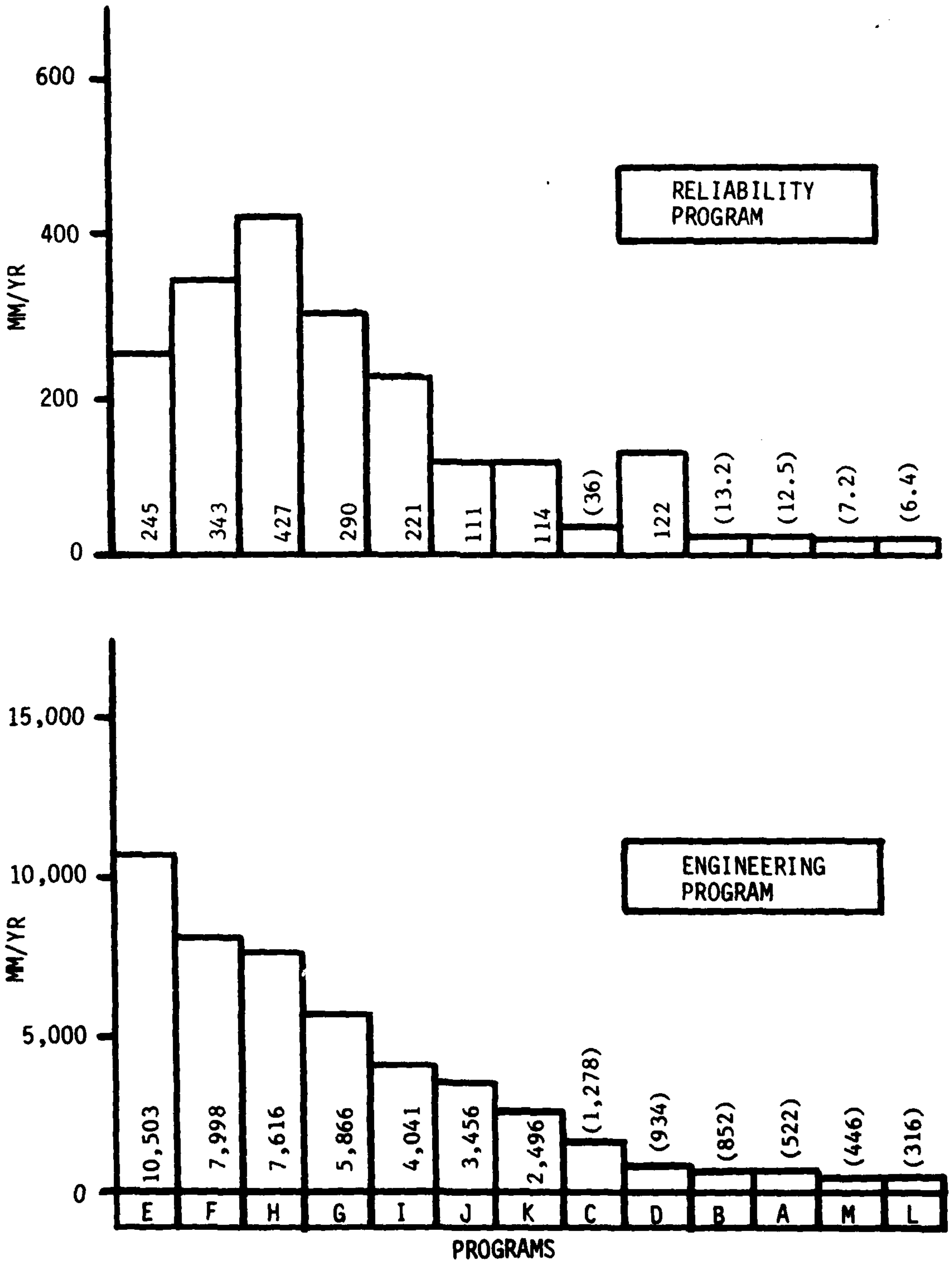
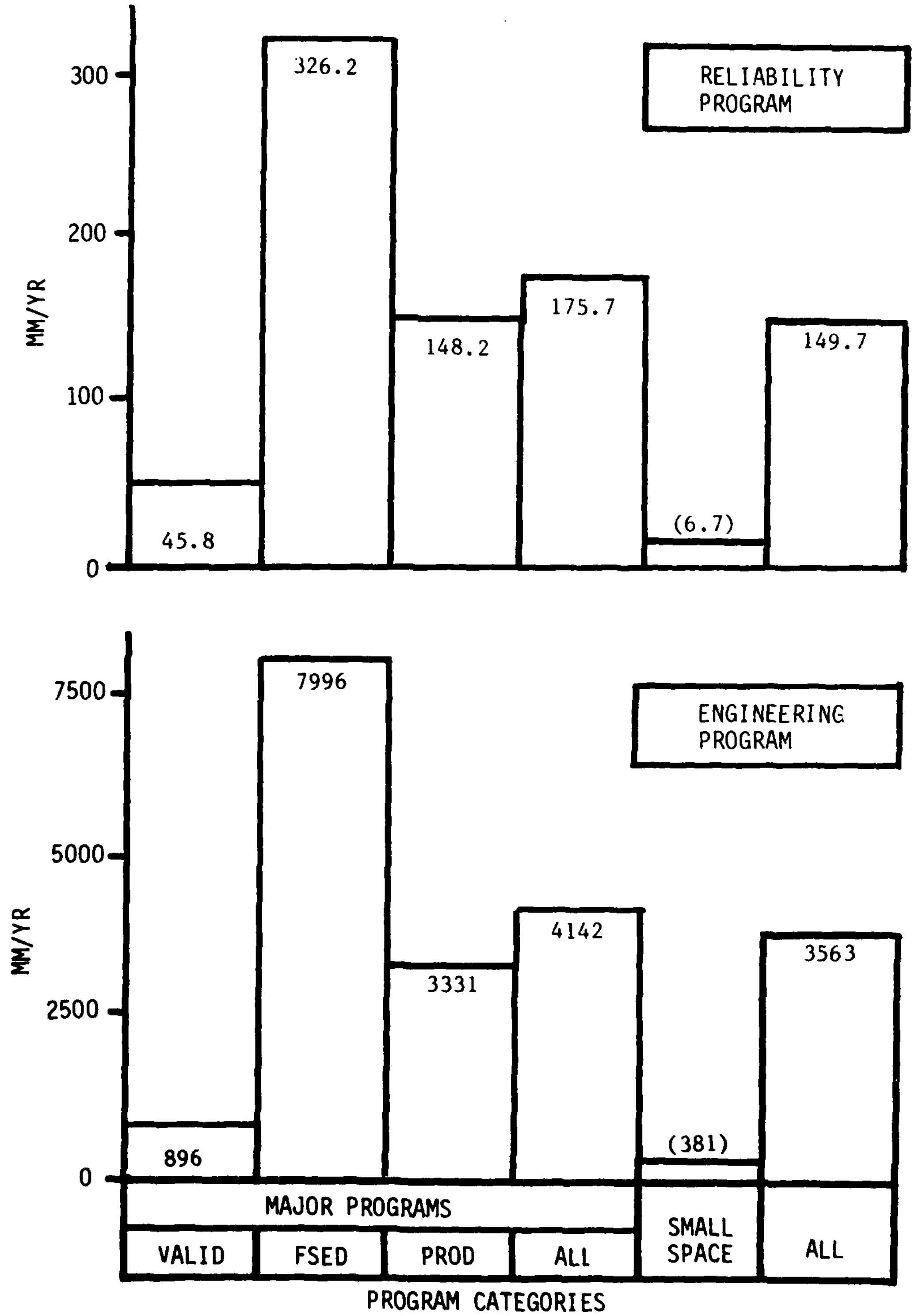


TABLE 2-3 - AVERAGE ENGINEERING AND RELIABILITY PROGRAM EXPENDITURES - MM/YR



(all programs except the two small spacecraft programs) range from an average of 326 MM/YR during FSED through an average of 148 MM/YR during the PROD phase to 46 MM/YR for the VALID phase.

Small space programs constitute an exception. This category of program is discussed in more detail in Section 3.0.

Table 2-4 summarizes the same reliability program expenditure data as presented in Tables 2-2 and 2-3, but in terms of engineering budget percentages. While considerable variation is displayed for the individual programs, the average values, with the exception of that for small space programs, show a remarkable consistency within the 4% to 5% level. The "tent pole" program, Program D, contained a part requalification activity where all part screening costs were charged to reliability.

Major program reliability task expenditures in terms of percentage of reliability budget are presented in Table 2-5 as a function of program phase. Similar displays as a function of program type are given in Table 2-6. The significance of the distribution of effort within a reliability program is discussed in Section 2.2.

TABLE 2-4 - INDIVIDUAL AND AVERAGE RELIABILITY PROGRAM EXPENDITURES - % OF ENGINEERING BUDGET

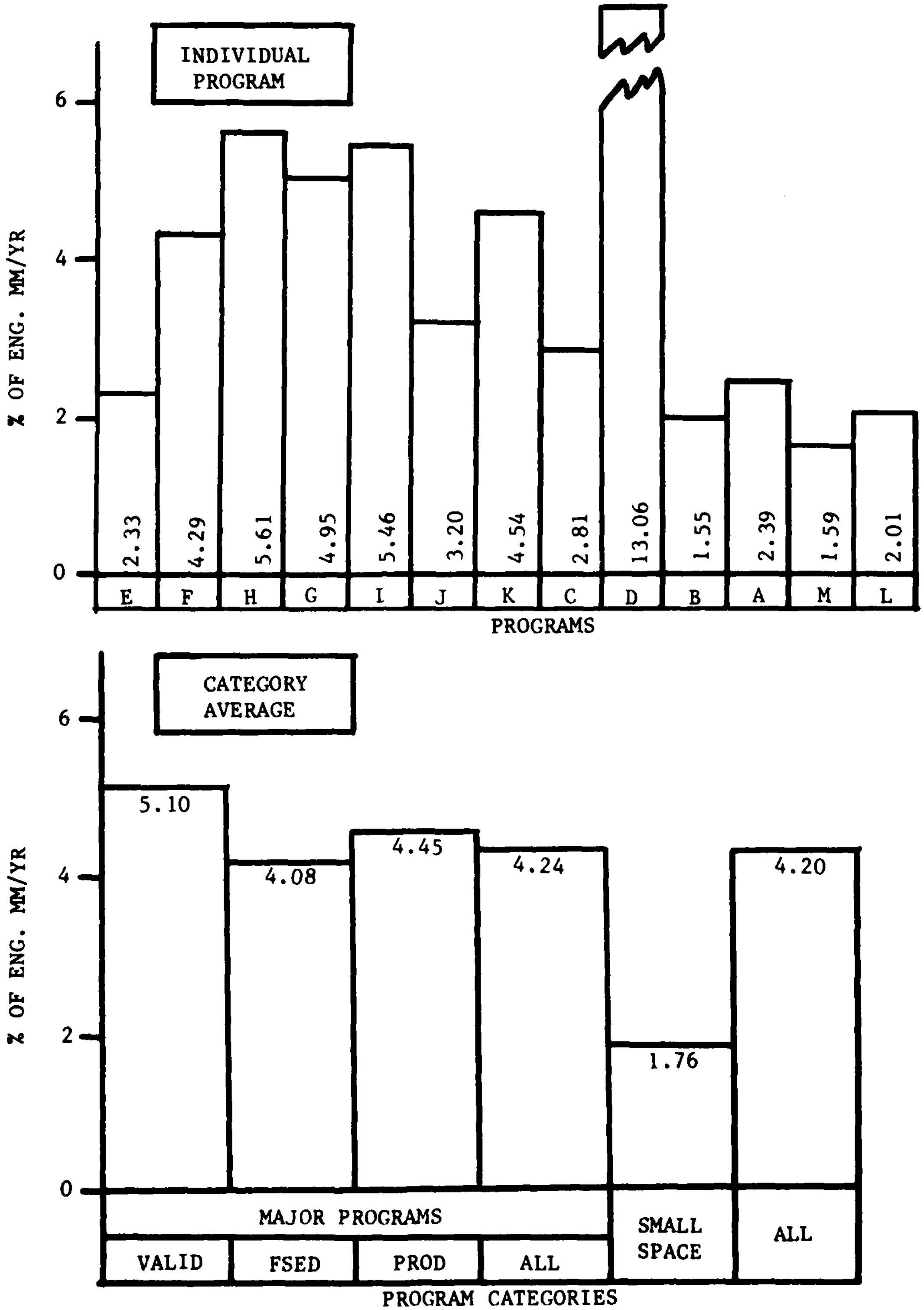


TABLE 2-5 - MAJOR PROGRAM RELIABILITY TASK EXPENDITURES BY PROGRAM PHASE - % OF RELIABILITY BUDGET

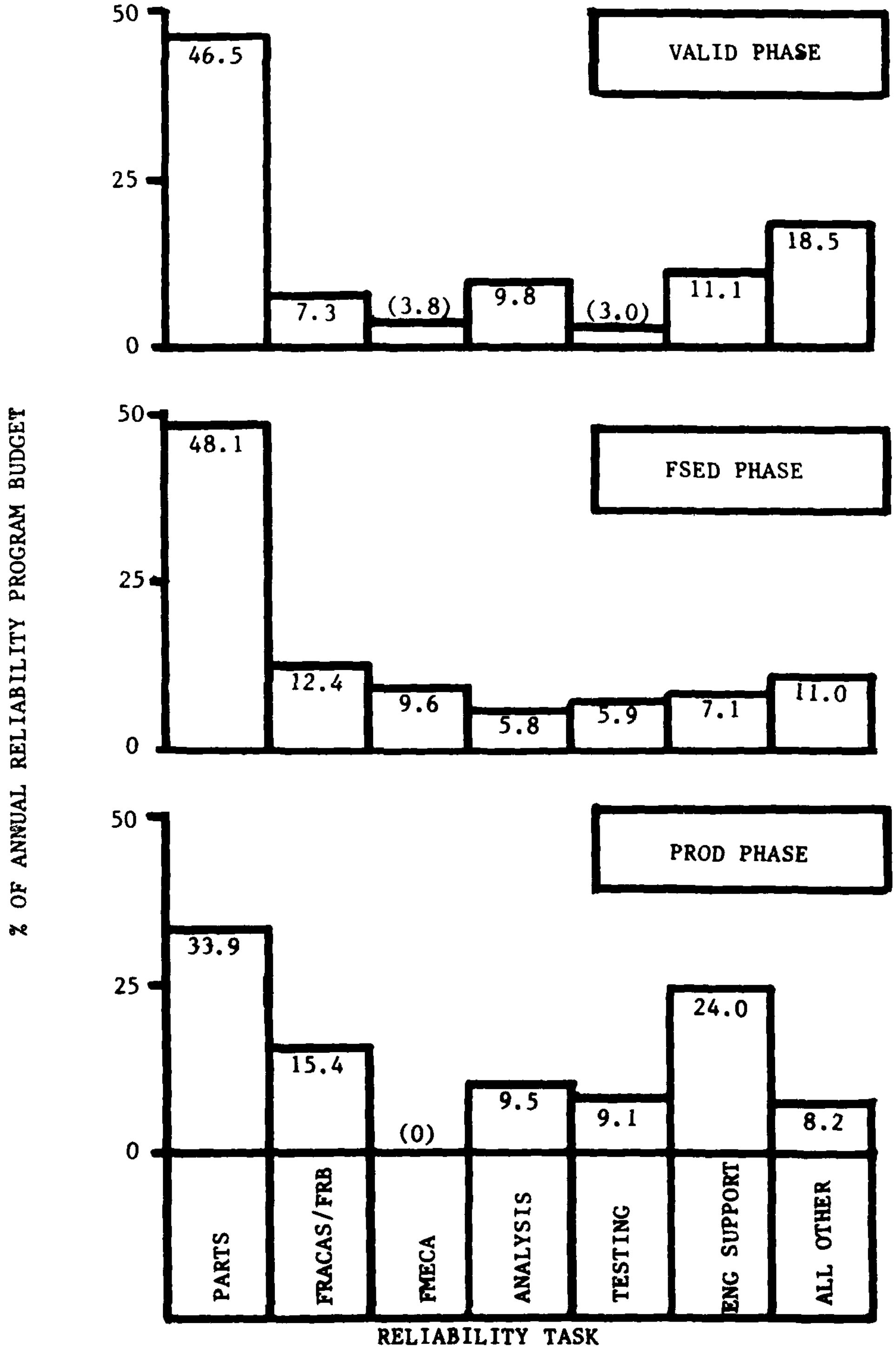
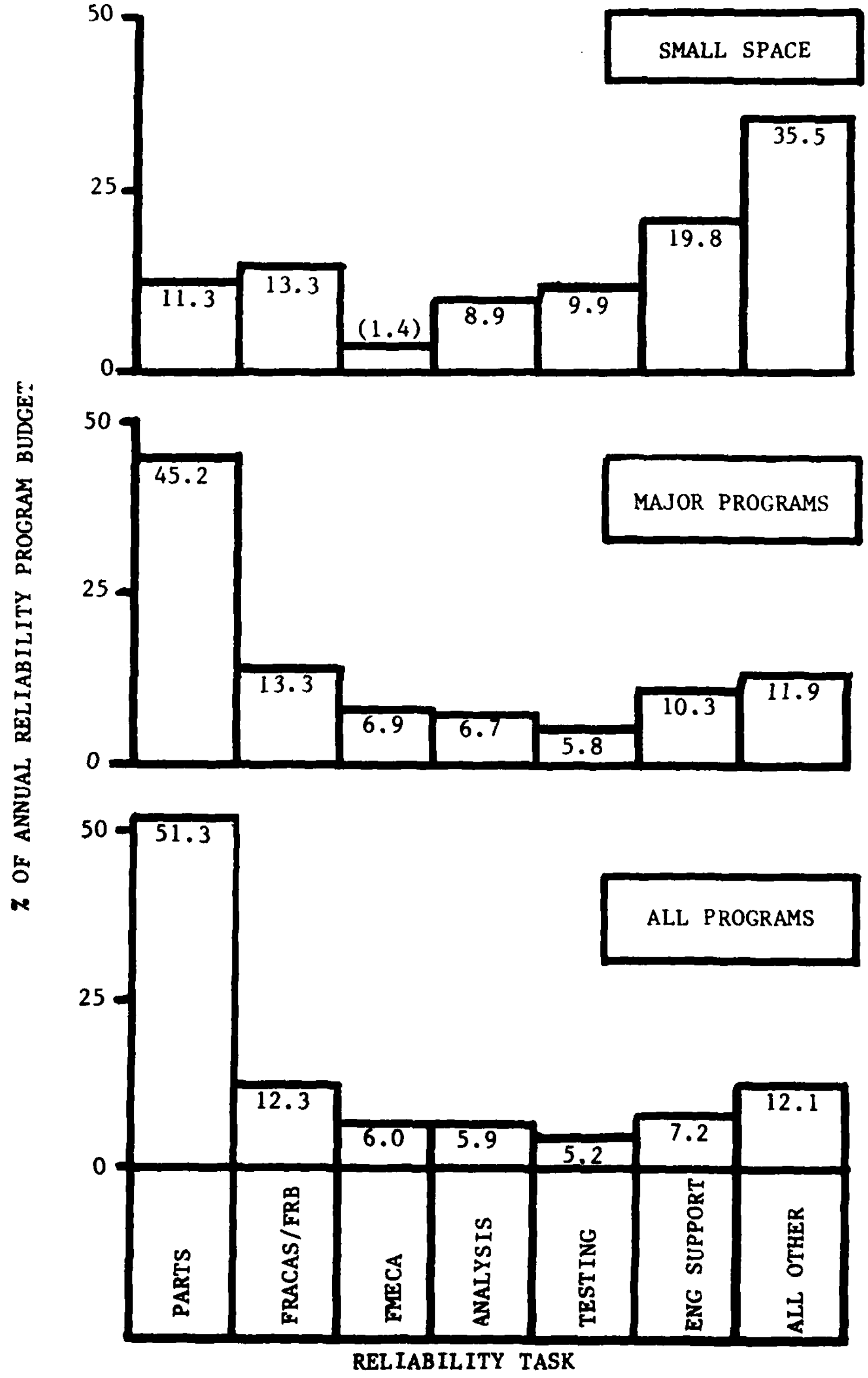


TABLE 2-6 - RELIABILITY TASK EXPENDITURES BY PROGRAM TYPE - % OF RELIABILITY BUDGET



Ranked comparisons of various measures of engineering and reliability effort expenditures, including those displayed in the previous tables, are given in Table 2-7. Shown for each of thirteen programs studied are; 1) measurement period, 2) total engineering budget for the measured period, 3) annual engineering budget, 4) total reliability budget for the measured period, 5) annual reliability budget, and 6) the ratio of the total reliability budget to the total engineering budget. Adjacent to each budget measure is the ranking of the measure from highest (1) to lowest (13).

A reasonably high degree of correlation is exhibited between the various measure pairs with the exception of the normalized measure of ratio of reliability budget to engineering budget which neutralizes the effects of program size. This measure masks some of the effects from program characteristics, such as complexity, for the same reason that it neutralizes the effects of program size. The correlated measures allow options in the selection of cost statistics depending on such factors as data availability and the particular object of the cost analysis.

TABLE 2-7 - RELIABILITY PROGRAM EXPENDITURES - MEASURE COMPARISON

PROGRAM DESIGNATION	PROGRAM PHASE	PROGRAM INTERVAL SAMPLED-YRS	TOTAL ENGINEERING BUDGET-MMS.		ENGINEERING MM/YR		TOTAL RELIABILITY BUDGET-MMS.		RELIABILITY MM/YR		REL. MM/YR / ENG. MM/YR (%)	
			RNK		RNK		RNK		RNK		RNK	
E	FSED	6.25	1	65,646	1	10,503	2	1,528	4	245	10	2.33
H	FSED	5.0	2	38,078	3	7,616	1	2,134	1	427	2	5.61
G	FSED	5.0	3	29,330	4	5,866	3	1,451	3	290	4	4.94
F	FSED	2.25	4	17,996	2	7,998	4	772	2	343	6	4.29
J	PROD	4.0	5	13,824	6	3,456	7	443	8	111	7	3.21
I	PROD	3.0	6	12,122	5	4,041	5	662	5	221	3	5.47
K	PROD	3.25	7	8.111	7	2,496	8	369	7	114	5	4.57
C	VALID	3.25	8	4,155	8	1,278	9	117	9	36	8	2.82
D	VALID	4.0	9	3,734	9	934	6	486	6	122	1	13.06
A	VALID	5.5	10	2,871	11	522	10	69	11	12.5	9	2.40
B	VALID	2.5	11	2,130	10	852	11	33	10	13.2	13	1.55
L	DEV/PROD	4.25	12	1,341	13	316	12	27	13	6.4	11	2.03
M	DEV/PROD	2.5	13	1,115	12	446	13	18	12	7.2	12	1.61

2.2 Reliability Cost Drivers

Reliability program cost drivers can be considered from two viewpoints: 1) high cost tasks relative to the total reliability effort and 2) high cost total reliability efforts as a result of particular program or system characteristics or features.

Referring to Table 2-5 of Section 2.1 of the Overview, a ranked listing of the top six tasks by relative cost and as a function of program phase is given in Table 2-8 below.

TABLE 2-8 - RELIABILITY TASK COST DRIVERS

TASK	VALIDATION	FSED	PRODUCTION
PARTS	47%	48%	34%
FRACAS/FRB	7%	12%	15%
ENGR. SUPPORT	11%	7%	24%
FMECA	4%	10%	0%
TESTING	3%	6%	9%
ANALYSIS	10%	6%	10%
TOTAL	82%	89%	92%

These cost driver tasks, which are discussed further below, absorb some 80-90% of the total reliability budget.

The parts task is the dominant task for all phases, ranging from 47%-48% during the VALID and FSED phases to 34% during the PROD phase. Other conspicuous tasks are FRACAS and a catch-all task called "engineering support". The latter task refers to those miscellaneous activities conducted by non-reliability engineering in support of reliability tasks. These activities, separate from the parts, SCA or tolerance analysis task efforts, are done in support of reliability analysis, FMECA's, subcontractor control, etc.

Reliability testing tasks, although potentially high cost, did not turn out to be cost drivers. There are two reasons for this outcome: 1) the more or less standard practice, where possible, of "piggybacking" reliability tests on tests designed for other purposes and 2) contractor costing practices of charging strict reliability test costs, including test articles, instrumentation, chamber hardware, etc. to either engineering or manufacturing budgets. What remains as reliability charges are the costs associated with defining reliability test requirements, the related planning for implementing these requirements and the monitoring of test results.

Another item of note is that total reliability program costs were approximately 4% of the engineering budget for both the FSED and PROD phases. Here it is seen that while the FMECA task drops to zero during production, the FRACAS actively increases by some 50%. Other tasks, including what is labeled as "modeling, allocation and prediction", but which include all analysis efforts, do not show significant shifts. The analysis efforts phase from a primarily predictive mode to an assessment (test data evaluation) mode.

Reliability cost drivers noted above are in terms of the relative cost per individual task. Cost drivers can also be viewed in terms of particular program/system characteristics or features which significantly impact reliability program/task costs. Results of a survey and an analysis of cost data on this subject are summarized below.

Questionnaires were sent to a number of reliability program manager and lead engineers asking them first to indicate those program or system characteristics which significantly impact (either plus or minus) individual task costs. Responses to this particular question are summarized in Table 2-9, "Majority Response Matrix". Indicated by an "X" are those task cost vs characteristic relationships which a majority of respondents deemed cost significant. As may be noted,

TABLE 2-9 - MAJORITY RESPONSE MATRIX

PROGRAM/ SYSTEM CHARACTERISTICS ↓ \ RELIABILITY PROGRAM TASKS →	MONITOR/CONTROL SUBCONTRACTORS	RELIABILITY MODELING, ALLOCATION & PREDICTION	FMECA (FAILURE MODES, EFFECTS & CRITICALITY)	SCA (SNEAK CIRCUIT ANALYSIS)	CIRCUIT TOLERANCE ANALYSIS (ELECTRONIC PARTS)	PMP (PARTS, MATERIALS & PROCESSES)	FRACAS (FAILURE REPORTING, ETC.)	ESS (ENVIRONMENTAL STRESS SCREENING - PRUT)	GROWTH TESTING OR TEST & FIX OR CERT	RELIABILITY QUAL. TEST INITIAL DEMO	PRODUCTION RELIABILITY ACCPT. TEST - DEMO	PROB. PACKAGE MGMT, FAIL. REV. BOARD, ETC.	EFF. OF FUNCT. TESTING, STORAGE, HOLDG, TRANSP. MAINT., ETC.
CONTRACT PHASE (CONCEPT, VALIDATION, FSED, PROD.)	X	X	X	X	X	X	X	X	X	X	X	X	X
CONTRACTOR ROLE (SYSTEM, ASSOC., SUB)	X												
% FAILURE RATE SUBCONTRACTED	X												
PRODUCTION QUANTITY							X					X	
SCHEDULE											X	X	
HARDWARE/SOFTWARE STATUS (NEW, MODIFIED, OFF-THE-SHELF)	X	X	X	X	X	X			X	X			
NO. OF ELEC. & MECH. PARTS		X	X	X	X	X	X					X	
NO. OF PART TYPES						X							
CONFIGURATION (SINGLE-THREAD, REDUNDANT, RESTOR.)		X	X	X									
MISSION DURATION		X	X		X								
NUMERICAL RQMT. LEVEL	X	X							X				
RELIABILITY CRITICALITY		X	X	X	X			X	X				
STORAGE LIFE RQMT													X
SERVICE LIFE RQMT													X
MAINT. CONCEPT (CERTIFIED ROUND, PERIODIC, ON-DEMAND)													X

a majority of respondents felt that program phase was a significant factor in all listed tasks. Other characteristics which were felt to have broad impact were hardware/software development status, complexity in terms of number of parts and reliability criticality.

A second item on the questionnaire was a request to give a ranked listing of the program or system characteristics as regards to cost impact. Results of the respondents replies are summarized in Table 2-10. Reasonable correlation is found between the priority listing of Table 2-10 and the majority response matrix of Table 2-9.

A comparison between the survey responses and the actual cost data from the programs shows agreement that program phase is the single most significant program or system characteristic in regard to cost impact. Other characteristics, such as hardware/software status and number of parts (complexity), do have impact on reliability program costs, but are masked when dealing with the percentage of engineering budget as a measure of reliability effort. Reference to engineering or reliability program manmonth per year expenditures and program part count (or number of part types) show a correlation between complexity and cost.

TABLE 2-10 - RANKED COST IMPACT LIST - PROGRAM/SYSTEM CHARACTERISTICS

PROGRAM/SYSTEM CHARACTERISTIC	SCORE
CONTRACT PHASE	68
NUMERICAL REQUIREMENT LEVEL	61
NO. OF PARTS	47
CONFIGURATION	41
HARDWARE/SOFTWARE STATUS	40
MISSION DURATION	40
MISSION ENVIRONMENT	33
RELIABILITY CRITICALITY	28
NO. OF PART TYPES (OR SUBSYSTEMS)	25
SCHEDULE	25
CONTRACTOR ROLE	23
PRODUCTION QUANTITY	18
UNIT COST	12
STORAGE LIFE REQUIREMENT	10
MAINTENANCE CONCEPT	9
% FAILURE RATE SUBCONTRACTED	8
SERVICE LIFE REQUIREMENT	4

RATING:	1	2	3	4	5	6	7	8	9	10
POINTS:	10	9	8	7	6	5	4	3	2	1

2.3 Reliability Program Cost Effectiveness

Actual measurement of reliability program effectiveness and the isolation of causes for lack of effectiveness is an extremely difficult, if not impossible, task. Of the thirteen programs surveyed, five have progressed to phases where measurement of achieved reliability is possible. In each of the five cases, the required reliability level has been achieved or exceeded (See Table A-9 of Appendix A) and in each of the programs certain reliability problems were encountered and solved. It is the latter activity, the discovery and solution of reliability problems, which has the real bearing on program effectiveness. A well planned and funded reliability effort can prevent or ferret out problems in a manner which minimizes program costs. Less efficient efforts might ultimately result in the same achieved levels of reliability, but at much greater program expenditures and possibly with delay in achieving operational status.

Further discussions on reliability cost effectiveness are contained in Section 4.0 - RELIABILITY PROGRAM TAILORING. This section contains both a general treatment of the tailoring topic such as

considerations of program effectiveness, time phasing, mechanics, etc. and a detailed treatment of tailoring decisions on a task-by-task basis.

3.0 RELIABILITY PROGRAM AND TASK COST ESTIMATION

While considerable effort has gone into the arrangement and display of reliability program/task cost data and associated tailoring considerations, maximum use of this guide requires effort and judgement on the part of the user. The very nature of tailoring implies a departure from the general or average case, a consideration of the unique features of a program/system and an appreciation of the dynamics of system development. Therefore, guide users are urged to bring their own specialized knowledge into play along with the information in the guide in order to achieve the most effective results.

3.1 Guideline Applicability

Historical cost data, used in developing the cost guidelines, reflect many underlying factors or conditions. They reflect a contractor's response, including any tailoring, budgetary or management influences, to program and system requirements as specified in the statement of work and referenced standards. They also reflect the type of system under development, the structure of the development process, the relationship existing between the contractor and the customer and other similar factors. Finally,

TABLE 3-1 - APPLICATION MATRIX

FEATURE	APPLICATION	
	SPECIFIC	WITH QUALIFICATION
• SYSTEM TYPE	MILITARY MISSILE & SPACE	*OTHER MILITARY SYSTEMS & NASA UNMANNED SPACE SYSTEMS*
• CONTRACTOR LEVEL	SYSTEM, ASSOCIATE	MAJOR SUBCONTRACTOR
• RELIABILITY PROGRAM STRUCTURE	MIL-STD-785, -1543	QR-800 & 801, NHB 5300.4
• DEVELOPMENT PROGRAM STRUCTURE	DoD - VALID, FSED, PROD	PHASE COMBINATIONS

they reflect, to some degree, the particular charging or costing practices of the contractor and the contractor's approach to reliability program implementation.

Some of the above factors have been formalized as program and system "characteristics" and their effects studied and evaluated. Other factors were not addressed, either because they were not measurable or because there was no experience base available for their evaluation. This latter category of factors, those factors not measured or not reflected in the experience base, place some limitations on the applicability of the data. These applicability limits are summarized in Table 3-1 and are discussed in more detail in the following paragraphs.

3.1.1 System Type

Guide data is specifically applicable to military missile and space systems ranging in complexity from large missile (ICBM) to small space (satellite). It is also applicable, with qualification, to other military systems and to NASA unmanned space systems. Applicability to other military systems depends on the degree of correspondence of their development process with that of missile and space systems. NASA reliability programs for unmanned space systems

are very close to military missile and space programs. Cost driver tasks such as parts, FRACAS and FMECA are very similar.

3.1.2 Contractor Level

Reliability program and task costs presented are based on those experienced by a single contractor performing at the system or associate contractor level. With some exceptions, notably in areas relating to integration of activities, the results are also believed applicable to the major subcontractor level. Cost biases due to contractor approach to reliability or to particular contractor charging practices are not believed significant. The influence of customer program and system requirements would appear to be a much more dominant factor than that of contractor approach. Any contractor charging biases were minimized by attempting to account for all reliability task costs regardless of the performing organization. A significant advantage of limiting the study to a single contractor was the ability to perform detailed investigations of all data base entries. These investigations were accomplished by means of follow-up interviews with reliability program managers and lead engineers associated with each surveyed program.

3.1.3 Development Program Structure

Eleven of the programs in the thirteen program data set generally followed structured development phases as defined in MIL-STD-785. Exceptions were the two small spacecraft programs which were developed and produced under a single contract phase. The structured phases as defined in MIL-STD-785 are listed below:

(1) Conceptual (CONCEPT) Phase: The identification and exploration of alternative solutions or solution concepts to satisfy a validated need.

(2) Demonstration and Validation (VALID) Phase: The period when selected candidate solutions are refined through extensive study and analyses; hardware development, if appropriate; test; and evaluations.

(3) Full-Scale Engineering Development (FSED) Phase: The period when the system and the principal items necessary for its support are designed, fabricated, tested and evaluated.

(4) Production (PROD) Phase: The period from production approval until the last system is delivered and accepted.

As noted in the Overview, the Concept Phase has not been addressed in the guide because of the lack of specific cost data associated with this phase of acquisition. As a normal practice, reliability costs during the concept phase are small and recorded integrally with other engineering charges. These efforts, consisting mainly of feasibility analyses and trade studies, are predominantly part time efforts and would generally be less than or at most equal to the percentage of engineering effort expended in the validation phase.

3.1.4 Reliability Program Structure

Reliability program structure is important both to understanding the historical cost data and to applying the data to new programs. It serves as a standard for defining the categories of reliability effort and for judging the scope of the individual reliability tasks.

DoD Directive 5000.40, "Reliability and Maintainability", and the Air Force implementing policy, AF Regulation 800-18, "Air Force Reliability and Maintainability Program", address the need to develop reliability programs with a balanced mix of <u>tailored</u> design engineering and management accountant tasks for <u>each program phase.</u> Referenced lower tier standards, MIL-STD-785, "Reliability Program

for Systems and Equipment Development and Production", and MIL-STD-1543, "Reliability Program Requirements for Space and Missile Systems", list the basic task options to be considered in the development of an acceptable program.

Twelve of the thirteen programs included in the cost data base were conducted within the framework of one or the other of the two referenced lower tier standards. The one exception, an Army missile program, was conducted under QR-800-M which is similar in structure and scope to MIL-STD-785. A summary and comparison of the reliability tasks contained in MIL-STD-785B and -1543 (Notice 2) is provided in Table 3-2.

Examination of Table 3-2 shows more or less general agreement between the tasks of MIL-STD-785B and MIL-STD-1543, Notice 2. Exceptions are Sneak Circuit analysis, Environmental Stress Screening and Monitor/Control Subcontractor and Supplier tasks contained in -785B and without counterpart in -1543. From a compliance viewpoint, the tasks of -1543 are generally more specific than those of -785B, calling for proportionately greater detail in tailoring decisions.

3.2 Cost Data Development

TABLE 3-2 - TASK COMPARISON - MIL-STD-785B VS MIL-STD-1543, NOTICE 2

MIL-STD-785B		MIL-STD-1543, NOTICE 2
NO.	TASK TITLE	CORRESPONDING PARAGRAPH
101	Reliability Program Plan	4.0 (Implicit)
102	Monitor/Control Sub. & Suppl.	No Explicit Task
103	Program Reviews	4.3 (Also Ref. MIL-STD-1521)
104	Failure Reporting Etc (FRACAS)	5.5
105	Failure Review Board	5.5.3
201	Reliability Modeling	5.4.1, 5.6
202	Reliability Allocations	5.4.1, 4.1, 5.6
203	Reliability Predictions	5.4.2, 5.3, 5.6
204	Failure Modes, Etc (FMECA)	5.2
205	Sneak Circuit Analysis (SCA)	No Explicit Task
206	Elec. Parts/Circ. Tol. Anal.	4.6
207	Parts Program	Prog Tailored, AF SAMSO-STD-73-2-C
208	Reliability Critical Items	4.4
209	Effects of Funct. Test Etc.	5.8, 5.7
301	Env. Stress Screen (ESS)	No Explicit Task
302	Rel. Develop/Gwth. Test	4.5.1, 4.2
303	Rel. Qual. Test	4.5.1, 4.2
304	Prod. Rel. Accpt. Test	4.2

3.2.1 Task Cost Categories

For purposes of this guide, the reliability tasks of MIL-STD-785B are employed as "standards" insofar as they are generally descriptive of categories of reliability efforts. Their use in association with defining task costs is not precise, however, and this fact should be taken into account in developing cost estimates and tailoring criteria.

In interpreting the task cost data presented in the guide, two sources of deviation from these standards should be noted. In the thirteen program data set only Program C, a validation phase effort, reflects a reliability program in accordance with the provisions of MIL-STD-785B. The majority of the remaining programs followed the provisions of either MIL-STD-785A or MIL-STD-1543. Second, the cost accounting practices on these programs did not follow work breakdown structures in exact correspondence with the specified program reliability tasks. Often, costs were recorded in combinations of tasks rather than individually.

Table 3-3 provides a comparison between the -785B tasks and the tasks used in the study to accumulate costs. The right hand column of the table shows three cases of task combination in regard to task

TABLE 3-3 - TASK COMPARISON MIL-STD-785B VS GUIDE

MIL-STD-785B		GUIDE	
NO.	TASK TITLE	NO.	TASK TITLE
101	Reliability Program Plan	1	Same
102	Monitor/Cont. Subcontractor	2	Same
103	Program Reviews	3	Same
104	Failure Reporting, Etc. (FRACAS)	4	FRACAS
105	Failure Review Board		
201	Reliability Modeling	5	Analysis (Also Includes Assessments)
202	Reliability Allocations		
203	Reliability Predictions		
204	Failure Modes, Etc. (FMECA)	6	Same
205	Sneak Circuit Analysis (SCA)	7	Same
206	Elec Parts/Circ. Tol. Anal.	8	Same
207	Parts Program	9	Same
208	Reliability Critical Items	10	Same
209	Effects of Funct. Test, Etc.	11	Same
301	Env. Stress Screening (ESS)	12	Reliability Testing
302	Rel. Develop/Growth Test		
303	Rel. Qual. Test		
304	Prod. Rel. Accpt. Test		

cost reporting. In each case, the combination includes only those tasks of like nature; e.g., FRACAS and FRB. The combined task titled "analysis" includes not only modeling allocation and prediction, but also the added activity of "assessment" which refers to evaluation by means of actual test or operational data. Reliability testing, as noted earlier, is defined to include only that effort associated with the development of reliability test requirements, procedures, evaluation criteria, etc. It does not include costs associated with test articles, chambers, instrumentation, test technicians, etc. These latter costs are recorded against either Engineering or Manufacturing depending on the test objective. For example, environmental stress screening is considered as a part of the normal manufacturing process resulting in the accounting practice of charging the test conduct costs to Manufacturing.

With the exceptions noted above on task combinations and task qualifications, the -785B task descriptions can be employed to approximate the scope and content of the "mainline" reliability tasks. Task descriptions, abstracted from -785B, are provided in Appendix C for guide user convenience.

Occasionally it is useful or required that reliability tasks be listed in accordance with the primary performing or coordinating function. The listing is also useful in isolating and estimating reliability program costs when these costs are accumulated at several centers. One categorization, developed from the experience of a system/associate level contractor, is shown in Table 3-4.

3.2.2 Cost Measures and Their Development

Two primary cost measures are used in the guide: manmonths per year and percentage of a defined budget. The manmonth per year measure, used both to describe intensity levels of total engineering and reliability efforts, provides an "absolute" standard and can be scaled to fit a program phase of any given duration. The percentage measure provides a useful relative standard both for scoping total program efforts and for scoping individual tasks.

Additionally, the percentage figure serves as a normalized measure discounting for the factor of program size. Thus, a rule of thumb for a typical FSED reliability program might be 4% of the total engineering manmonths per year or 4% of the total engineering budget for the entire FSED phase (under the assumption of uniform effort intensity). In a similar manner, costs of individual reliability

TABLE 3-4 - TASK CATEGORIES

MIL-STD-785B TASK NO.	CATEGORY	DESCRIPTION
101 102 103 104 105 201 202 203 204 208 290 301 302 303 304	I	Task normally performed or coordinated by the reliability project organization.
207	II	PMP control task normally performed by a technical staff group assigned to project.
205 206	III	Tasks other than PMP normally performed by project or supporting technical staff groups.
(OTHER)		General engineering support given to the project reliability group in performance of Category I tasks.

tasks or task combinations could be expressed as a percentage of the reliability program budget.

Basic cost data, developed for use in the guidelines, were derived from recorded or planned "manmonth" expenditures maintained on each missile/space program surveyed. For each program, expenditures were accumulated for a defined interval which varied between a minimum of 27 months to a maximum of 75 months. For most cases, these sampling intervals were chosen either to correspond to or lie within a given program phase.

For each program within a defined program phase or sampling interval, manmonth expenditure data were grouped within three categories: 1) engineering, 2) reliability and 3) specific reliability tasks as defined subdivisions of categories 1) or 2) or both. Interval and annual manmonth expenditures as well as normalized percentage expenditures were developed for the categories defined above.

3.3 Cost Estimating Procedure

This section presents the cost data and procedures for estimating total reliability program and individual reliability task costs for

missile and space systems. Minimum information required for use of the data and procedures are definitions of the system type (major acquisition or small space) and the phase(s) of development (VALID, FSED, PROD).

Table 3.5 outlines the two categories of estimation methods presented. Method I is for use with small space programs and major acquisition systems which are minimally defined; i.e., information on system characteristics other than program type and development phase are not available. Method II is exclusively for well defined major acquisition programs and systems where information on other characteristics such as complexity, configuration and hardware status are available.

Both Methods I and II also use an estimate of the program engineering budget to develop specific manmonth cost data for the various reliability tasks and total programs. If available, the program engineering budget can be considered another of the user supplied system characteristics.

When the program engineering budget is not available, or only generally known in terms of high or low boundary conditions, guidelines are provided to aid in forming an initial estimate.

TABLE 3-5 - PROCEDURE METHOD MATRIX

	PROGRAM/SYSTEM CHARACTERISTICS			ENGINEERING BUDGET INFORMATION
	SYSTEM TYPE	PROGRAM PHASE(S)	OTHER	
METHOD I	KNOWN - PREREQUISITE DATA	KNOWN - PREREQUISITE DATA	UNKNOWN	UNKNOWN (IA)
				KNOWN - OR ESTIMATED (IB)
METHOD II			KNOWN	KNOWN - OR ESTIMATED

Both cost estimating methods have the same basic approach: reliability task costs are estimated independently in terms of percentage of engineering budget, and are then combined to form the total reliability program costs. The program engineering budget estimate is then used to translate these values into specific manmonths per year cost measures.

The above describes two of the cost measures produced by the two methods. The complete set includes:

- Total Reliability Program Cost - MM/Year
- Total Reliability Program Cost - % of Engr. Budget
- Reliability Task Costs - MM/Year
- Reliability Task Costs - % of Engr. Budget
- Reliability Task Costs - % of Rel. Budget

Each method is described by step-by-step procedures which include sample work sheets and example problems. Data tables and associated information appropriate to the use of each method are collected in Sections 3.3.2 and 3.3.3.

It may be noted that derived reliability cost values differ from their counterparts reported in Section 2.0 (Overview). These

deviations can be traced to differences in objectives and data qualification. In the Overview, the intent was to show, from a historical perspective, the costs incurred on a selected collection of missile and space programs. In satisfying this objective, summary statistics were developed from the cost data as reported and without detailed qualification.

In contrast to providing historical perspective, the objective of this section is to develop procedures and data for estimating the reliability program and task costs associated with the tailored application of MIL-STD-785B tasks to missile and space programs. As a result, the raw cost data has been "scrubbed" to eliminate data items not representative of a standard 785B application. Most often, the eliminated data points reflected a tailoring beyond -785B standards. The cost estimating data charts used herein are based on this modified data set and reflect the standard application of the respective MIL-STD-785B reliability tasks. Tailoring of the resultant costs is treated in Section 4.0. Details of the respective data bases are reported in Appendix A.

3.3.1 Engineering Budget Estimation

A prerequisite data item for both cost estimation procedures is the annual program engineering budget. If available, an initial program estimate should be used for the system under consideration. When no estimate is available, one can be developed from the the data in Table 3.6. This table shows the average program expenditures in MM/year for Small Space systems and for Major Acquisition systems, with the latter category segregated by development phase (VALID, FSED, PROD). If no knowledge of system complexity or of the proposed program budget is available, it is recommended that an average program budget be used in the cost estimation procedures.

In some cases because of system complexity, program size, or other general system characteristics, this average budget may not be considered valid. For these cases, budget ranges are presented to aid in estimating an appropriate program budget.

The following general guidelines developed from observations on the data are provided as additional aids:

- The major influence on program budgets was found to be system complexity - the more complex systems had the higher costs.

- A secondary influence was found to be the procurement schedule - accelerated schedules had higher annual engineering budgets.
- Another secondary influence observed was program size. Generally high production programs had higher costs.

3.3.2 Cost Estimating Procedure - Method I

Cost estimating procedures for small space systems are covered exclusively by Method I. The use of Method I is also appropriate for major acquisition programs which are only minimally defined but where the development phase (VALID, PSED, PROD) is specified.

The estimating data base is the typical or average reliability program task costs developed from thirteen missile and space programs. Two options are presented (Methods IA and IB). The first option is appropriate when only minimal information on the program engineering budget is available. The second option assumes availability of an estimate of the engineering budget either as a given or as estimated from Table 3.6.

TABLE 3-6 - ENGINEERING PROGRAM EXPENDITURES - MM/YR

PROGRAM/PHASE	PROGRAM EXPENDITURES - MM/YR		
	AVERAGE	LOW	HIGH
MAJOR PROGRAM			
VALID	896	522	1278
FSED	7995	5866	10503
PROD	3330	2496	4040
SMALL SPACE	380	315	446

Both options utilize typical reliability task costs measured by percentage of engineering budget and apply these against engineering budget estimtes to produce MM/year statistics.

3.3.2.1 Method IA - Engineering Budget Unknown

When no estimate of program engineering budget is available, reliability program and task costs can be read directly from Table 3-7 . These data are the typical (average) task costs observed in the modified data base. Their distribution among the total reliability program is shown in Table 3-9.

3.3.2.2 Method IB - Engineering Budget Known or Estimated

Method IB uses an engineering budget estimate from known program data or from Table 3-6 to develop reliability programs and task MM/year data. Basic to Method IB is the typical reliability program task costs measured as a percentage of engineering budget (Table 3-8).

TABLE 3-7 - AVERAGE RELIABILITY PROGRAM AND TASK EXPENDITURES - MM PER YEAR

PROGRAM/PHASE TASK	MAJOR PROGRAM			SMALL SPACE
	VALID	FSED	PROD	
PROGRAM PLAN	.86	.38	.00	.36
MONITOR & CONTROL SUBCONTRACTOR	1.32	13.71	9.25	.60
PROGRAM REVIEWS	1.29	6.61	1.92	1.61
FRACAS & FRB	4.42	40.3	27.5	.89
ANALYSIS	4.50	19.07	16.51	.60
FMECA	1.30	32.49	---	.10
SCA	--	---	---	---
ELEC. PARTS/CIRC. TOLERANCE ANALYSIS	1.6	12.05	---	---
PARTS	2.34	196.77	53.33	.75
CRITICAL ITEMS	.60	.50	.19	---
EFFECTS OF TEST., STORAGE, ETC.	1.62	2.82	3.12	---
TESTING	2.72	37.68	15.28	.67
ENG. SUPPORT	4.34	23.21	28.35	1.33
TOTAL	26.91	385.59	155.45	6.91

TABLE 3-8 - AVERAGE RELIABILITY PROGRAM AND TASK EXPENDITURES - % OF ENGINEERING BUDGET

PROGRAM/PHASE TASK	MAJOR PROGRAM			SMALL SPACE
	VALID	FSED	PROD	
PROGRAM PLAN	.096	.005	--	.09
MONITOR & CONTROL SUBCONTRACTOR	.147	.174	.280	.16
PROGRAM REVIEWS	.147	.082	.056	.42
FRACAS & FRB	.492	.5061	.827	.23
ANALYSIS	.501	.236	.495	.16
FMECA	.144	.405	--	.03
SCA	--	--	--	--
ELEC. PARTS/CIRC. TOLERANCE ANALYSIS	.177	.149	--	--
PARTS	.261	2.458	1.602	.2
CRITICAL ITEMS	.066	.005	.047	--
EFFECTS OF TEST., STORAGE, ETC.	.18	.034	.093	--
TESTING	.303	.472	.458	.18
ENG. SUPPORT	.483	.289	.850	.35
TOTAL	3.00	4.82	4.67	1.81

TABLE 3-9 - METHOD I RELIABILITY TASK EXPENDITURES - % OF RELIABILITY PROGRAM BUDGET

TASK \ PROGRAM/PHASE	MAJOR PROGRAM			SMALL SPACE
	VALID	FSED	PROD	
PROGRAM PLAN	3.2	.1	--	5.2
MONITOR & CONTROL SUBCONTRACTOR	4.9	3.6	6.0	8.7
PROGRAM REVIEWS	4.9	1.7	1.2	23.3
FRACAS & FRB	16.4	10.5	17.7	12.9
ANALYSIS	16.7	4.9	10.6	8.7
FMECA	4.8	8.4	--	1.4
SCA	--	--	--	--
ELEC. PARTS/CIRC. TOLERANCE ANALYSIS	5.9	3.1	--	--
PARTS	8.7	51.0	34.30	10.9
CRITICAL ITEMS	2.2	.1	.1	--
EFFECTS OF TEST., STORAGE, ETC.	6.0	.7	2.0	--
TESTING	10.1	9.8	9.8	9.7
ENG. SUPPORT	16.1	6.0	18.2	19.2
TOTAL	100.0	100.0	100.0	100.0

The procedure described below is summarized in a companion worksheet, Table 3-10. An example calculation is shown in Table 3-11.

Step 1 - Confirm applicability of data to candidate system and program. Reference Section 3.1

Step 2 - Identify system type (major acquistion or small space) and development phase (VALID, FSED, PROD) if major acquisition. For more than one phase, repeat following steps for each phase.

Step 3 - If engineering budget is unknown, estimate budget from Table 3-6. Reference Section 3.3.1.

Step 4 - Obtain reliability program and task costs (percentage of engineering budget) from appropriate column of Table 3-8.

Step 5 - Apply percentage figures of Step 4 to engineering budget figure (Step 3)

Step 6 - Determine % of reliability budget values from Table 3-9.

TABLE 3-10 - METHOD I WORKSHEET

ENGINEERING BUDGET _______MM/YR (ACTUAL)

(LIST ACTUAL OR ESTIMATED) _______MM/YR (ESTIMATED-TABLE 3-6)

RELIABILITY TASK	% ENG. BUDGET	ANNUAL REL. BUDGET-MM/YR	% REL. BUDGET
(COLUMN 1)	(COLUMN 2)	(COLUMN 3)	(COLUMN 4)
PROGRAM PLAN	(ENTRIES FROM TABLE 3-8)	(COL. 2X ESTIMATE OR ACTUAL FROM ABOVE)	(ENTRIES FROM TABLE 3-9)
MONITOR & CONTROL SUBCONTRACTORS SUB PROGRAM REVIEWS			
FRACAS & FRB			
ANALYSIS			
FMECA			
SNEAK CIRC. ANAL.	(SEE DISCUSSION IN SECTION 4.3)		
ELEC. PARTS/CIRC. TOLERANCE ANALYSIS			
PARTS			
CRITICAL ITEMS			
EFFECTS OF TEST, STORAGE, ETC.			
TESTING			
ENG. SUPPORT			
TOTAL			100%

TABLE 3-11 - EXAMPLE METHOD I CALCULATION
(MAJOR ACQUISITION-VALID PHASE)

ENGINEERING BUDGET 1100 MM/YR (ACTUAL)

(LIST ACTUAL OR ESTIMATED) ________ MM/YR (ESTIMATED-TABLE 3-6)

RELIABILITY TASK	% ENG. BUDGET	ANNUAL REL. BUDGET-MM/YR	% REL. BUDGET
(COLUMN 1)	(COLUMN 2)	(COLUMN 3)	(COLUMN 4)
PROGRAM PLAN	.096	1.06	3.2
MONITOR & CONTROL SUBCONTRACTORS	.147	1.62	4.9
PROGRAM REVIEWS	.147	1.62	4.9
FRACAS & FRB	.492	5.41	16.4
ANALYSIS	.501	5.51	16.7
FMECA	.1441	1.58	4.8
SNEAK CIRC. ANAL.	---	---	---
ELEC. PARTS/CIRC. TOLERANCE ANALYSIS	.177	1.95	5.9
PARTS	.261	2.87	8.7
CRITICAL ITEMS	.066	.73	2.2
EFFECTS OF TEST, STORAGE, ETC.	.180	1.98	6.0
TESTING	.303	3.33	10.1
ENG. SUPPORT	.483	5.32	16.1
TOTAL	3.00	33.0	100%

3.3.3 Cost Estimating Procedure - Method II

Cost estimating Method II is limited to major acquisition missile programs whose characteristics such as complexity, configuration, hardware status are known or can be accurately estimated. As noted previously, small space programs are covered exclusively by Method I, Section 3.3.2.

Method II employs a set of linear regression equations to estimate reliability task costs measured as a percentage of engineering budget. These equations relate various MIL-STD-785B reliability task costs to specific system characteristics. A set of ten system characteristics are used in the cost estimating equations. This set, along with a numerical scoring criteria for use in the regression equations, is shown in Table 3-12. Most of the characteristics are scored nominal (0), above nominal (positive score) or below nominal (negative score). Exceptions to this scoring include program phase, the phase II term to account for nonlinearities and the readiness requirement scored as (1) for present or (0) for not present.

TABLE 3-12 - PROGRAM/SYSTEM CHARACTERISTIC DEFINITIONS & SCORING CRITERIA

PROGRAM PHASE (I)	VALID FSED PROD	-1 0 1
PROGRAM PHASE (II)	VALID FSED PROD	-1 0 1
RELIABILITY CRITICALITY	COST EFFECTIVE BELOW NOMINAL NOMINAL ABOVE NOMINAL EXTREME	-1 -.5 0 .5 1
COMPLEXITY (PART COUNT)	4999 OR LESS 5000 - 9999 10000 - 19999 20000 - 49999 50000 - OR MORE	-2 -1 0 1 2
HARDWARE STATUS	OFF THE SHELF MODIFIED NEW	-1 0 1
NUMBER OF PART TYPES	999 OR LESS 1000 TO 1999 2000 TO 3999 4000 TO 7999 8000 OR MORE	-2 -1 0 1 2
MISSION REQ.	BELOW SOA NOMINAL DIFFICULT	-1 0 1
READINESS REQ.	YES THEY HAVE ONE NO THEY DON'T	1 0
PERCENTAGE OF FAILURE RATE SUBCONTRACTED	0% - 35% 35% - 65% 65% - 100%	-1 0 1
CONFIGURATION	SINGLE THREAD REDUNDANT RESTORABLE	-1 0 1

The regression equations require a definitive (inputted) score for the phase I and phase II terms. All other characteristic scores can default to zero (nominal) if no definition of the particular characteristic is available.

Equations were developed for nine of the thirteen reliability task cost categories. The remaining task costs are estimated by means of the typical costs developed for Method I.

For each task, three cost estimating regression equations using combinations of one, two, and three system characteristics were developed. Supplementary investigations had shown insignificant *impact on task costs* beyond consideration of combinations of up to three characteristics. For reliability program cost estimating purposes, one of the three candidate equations was selected for each task. This set, labeled "Best" is shown in Table 3-13. Equation selection was based on an evaluation of changes in the standard error estimate and regression coefficients resulting from each characteristic addition. Further details of this process along with the complete set of regression equations are contained in Appendix B.

The most consistent attribute in the set of cost estimating equations relates to program phase; either Phase, Phase II or both.

TABLE 3-13 - TASK COST ESTIMATING EQUATIONS ("BEST SET")

EQUATION: TASK COST (% ENG. BUDGET) = $A + B_1X_1 + B_2X_2 + B_3X_3$

WHERE:
- A = CONSTANT
- B_i = COST COEFFICIENT
- X_i = PROGRAM/SYSTEM CHARACTERISTIC (SCORE INPUT)

RELIABILITY TASK	A	B_1	X_1	B_2	X_2	B_3	X_3	CORRELATION
MONT. & CONT. SUBCONT.	.22	.08	PHASE (I)	-.07	STATUS			.72
PROGRAM REVIEWS	.08	-.04	COMPLEXITY					.74
FRACAS & FRB	.64	.22	PHASE (I)	.17	PHASE (II)	-.21	% F.R. SUB.	.91
ANALYSIS	.26	.22	PHASE (II)	-.08	CRITICALITY	-.06	STATUS	.89
FMECA	.63	-.53	PHASE (II)	-.27	STATUS			.95
PARTS	2.78	.68	PHASE (I)	-1.90	PHASE (II)			.96
CRITICAL ITEMS	.00	.05	PHASE (II)	.03	COMPLEXITY	-.04	NO.PART TYPES	.81
EFFECTS OF TEST, ETC.	.00	.28	READINESS	.07	STATUS	.04	NO.PART TYPES	.90
TESTING	.37	-.07	CRITICALITY	.03	COMPLEXITY	.05	STATUS	1.00

The dominance of program phase is further illustrated by comparing the respective program attribute coefficients in Table 3-13. In general, those coefficients associated with phase parameters are significantly higher than those associated with other program characteristics or attributes. Generally, the task cost equations can be viewed as an average value, A, which is adjusted by program phase, and to a lesser extent, by other system attributes. With few exceptions, e.g., the readiness attribute on storage studies, the influence of these lesser attributes is neither intuitive nor consistent. While the exact reasons for these results are not obvious, a masking of relationships between the overall program cost data, and, by association, the reliability cost data, and system attributes is a factor. This means that for more complex and state of the art programs, not only are absolute reliability task costs increased, but also overall program costs are increased proportionally. This, in effect, disguises any influence on the chosen measure. Measures other than percentage of engineering budget (e.g., MM/YR) could have been employed to avoid the masking, however, these were not used in the correlation analysis to preclude domination by results from a few large programs. Despite these inconsistencies, the tabled equations and correlations are, nevertheless, accurate reflections of the respective program attributes on task costs as observed from the modified data base.

As such, they can be used to predict reliability task costs for systems similar to those described herein.

PROCEDURE:

Step 1 - Confirm applicability of data to candidate system and program. Reference Section 3.1

Step 2 - Define required system characteristics and score per Table 3-12 criteria.

Step 3 - If engineering budget is unavailable, estimate budget from Table 3-6. Reference Section 3.3.1

Step 4 - Exercise regression equations, Table 3-13 and Table 3-15, using system characteristic scores from Step 2.

Step 5 - Obtain cost percentages for tasks not covered by regression equations from Table 3-8.

Step 6 - Apply percentage figure of Steps 4 and 5 to engineering budget figure of Step 3.

Step 7 - Determine % of reliability budget values by taking ratios of task costs to total reliability program cost.

TABLE 3-14 - METHOD II SUMMARY WORKSHEET

ENGINEERING BUDGET: ______MM/YR (ACTUAL)

(LIST ACTUAL OR ESTIMATED) ______MM/YR (ESTIMATED-TABLE 3-6)

RELIABILITY TASK	% ENG. BUDGET	ANNUAL REL. BUDGET-MM/YR	% REL. BUDGET
(COLUMN 1)	(COLUMN 2)	(COLUMN 3)	(COLUMN 4)
PROGRAM PLAN	(ENTRY FROM TABLE 3-8)	(COL. 2 X ESTIMATE OR ACTUAL FROM ABOVE)	(ENTRIES = COL. 2 ENTRIES/ COL. 2 TOTAL)
MONITOR & CONTROL SUBCONTRACTORS	(ENTRIES FROM TABLE 3-15 WORK-SHEET)		
PROGRAM REVIEWS			
FRACAS & FRB			
ANALYSIS			
FMECA			
SNEAK CIRC. ANAL.	(SEE DISCUSSION IN SECTION 4.3)		
ELEC. PARTS/CIRC. TOLERANCE ANALYSIS	(ENTRY FROM TABLE 3-8)		
PARTS	(ENTRIES FROM TABLE 3-15 WORK-SHEET)		
CRITICAL ITEMS			
EFFECTS OF TEST, STORAGE, ETC.			
TESTING			
ENG. SUPPORT	(ENTRY FROM TABLE 3-8)		
TOTAL			100%

TABLE 3-15 - RELIABILITY TASK COST REGRESSION EQUATION WORKSHEET

RELIABILITY TASK	CHARACTERISTIC	SCORE	MULT.	COST SUB	COST TOTAL
MONITOR & CONTROL SUBCONTRACTORS	CONSTANT	.22	1	.22	
	PHASE (I)	--	.08	--	
	STATUS	--	-.07	--	---
PROGRAM REVIEWS	CONSTANT	.08	1	.08	
	COMPLEXITY	--	-.04	--	---
FRACAS & FRB	CONSTANT	.64	1	.64	
	PHASE (I)	--	.22	--	
	PHASE (II)	--	.17	--	
	% F.R. SUB.	--	-.21	--	---
ANALYSIS	CONSTANT	.26	1	.26	
	PHASE (II)	--	.22	--	
	CRITICALITY	--	-.08	--	
	STATUS	--	-.06	--	---
FMECA	CONSTANT	.63	1	.63	
	PHASE (II)	--	-.53	--	
	STATUS	--	-.27	--	---
PARTS	CONSTANT	2.78	1	2.78	
	PHASE (I)	--	.68	--	
	PHASE (II)	--	-1.90	--	---
CRITICAL ITEMS	PHASE II	--	.05	--	
	COMPLEXITY	--	.03	--	
	NO. PART TYPES	--	-.04	--	---
EFFECTS OF TESTING, STORAGE, ETC.	READINESS	--	.28	--	
	STATUS	--	.07	--	
	NO. PART TYPES	--	.04	--	---
TESTING	CONSTANT	.37	1	.37	
	CRITICALITY	--	-.07	--	
	COMPLEXITY	--	.03	--	
	STATUS	--	.03	--	---

TABLE 3-16 - EXAMPLE METHOD II SUMMARY WORKSHEET
(MAJOR ACQUISITION - PROD PHASE)

ENGINEERING BUDGET: ______MM/YR (ACTUAL)

(LIST ACTUAL OR ESTIMATED) 3500 MM/YR (ESTIMATED-TABLE 3-6)

RELIABILITY TASK	% ENG. BUDGET	ANNUAL REL. BUDGET-MM/YR	% REL. BUDGET
(COLUMN 1)	(COLUMN 2)	(COLUMN 3)	(COLUMN 4)
PROGRAM PLAN	0	0	0
MONITOR & CONTROL SUBCONTRACTORS	.23	8.05	4.98
PROGRAM REVIEWS	.08	2.80	1.73
FRACAS & FRB	1.03	36.05	22.32
ANALYSIS	.38	13.30	8.23
FMECA	0	0	0
SNEAK CIRC. ANAL.	--	--	--
ELEC. PARTS/CIRC. TOLERANCE ANALYSIS	0	0	0
PARTS	1.56	54.60	33.80
CRITICAL ITEMS	.01	.35	.22
EFFECTS OF TEST, STORAGE, ETC.	.11	3.85	2.38
TESTING	.365	12.78	7.91
ENG. SUPPORT	.85	29.75	18.42
TOTAL	4.615	161.53	100%

TABLE 3-17 - EXAMPLE RELIABILITY TASK COST REGRESSION EQUATION WORKSHEET

				COST	
RELIABILITY TASK	CHARACTERISTIC	SCORE	MULT.	SUB	TOTAL
MONITOR & CONTROL SUBCONTRACTORS	CONSTANT	.22	1	.22	
	PHASE (I)	1	.08	.08	
	STATUS	1	-.07	-.07	.23
PROGRAM REVIEWS	CONSTANT	.08	1	.08	
	COMPLEXITY	0	-.04		.08
FRACAS & FRB	CONSTANT	.64	1	.64	
	PHASE (I)	1	.22	.22	
	PHASE (II)	1	.17	.17	
	% F.R. SUB.	0	-.21	0	1.03
ANALYSIS	CONSTANT	.26	1	.26	
	PHASE (II)	1	.22	.22	
	CRITICALITY	.5	-.08	-.04	
	STATUS	1	-.06	-.06	.38
FMECA	CONSTANT	.63	1	.63	
	PHASE (II)	1	-.53	-.53	
	STATUS	1	-.27	-.27	▷
PARTS	CONSTANT	2.78	1	2.78	
	PHASE (I)	1	.68	.68	
	PHASE (II)	1	-1.90	-1.90	1.56
CRITICAL ITEMS	PHASE II	1	.05	.05	
	COMPLEXITY	0	.03	0	
	NO. PART TYPES	1	-.04	-.04	.01
EFFECTS OF TESTING, STORAGE, ETC.	READINESS	0	.28	0	
	STATUS	1	.07	.07	
	NO. PART TYPES	1	.04	.04	.11
TESTING	CONSTANT	.37	1	.37	
	CRITICALITY	.5	-.07	-.035	
	COMPLEXITY	0	.03	0	
	STATUS	1	.03	.03	.365

▷ NEGATIVE VALUE - INTERPRET AS ZERO COST FOR THIS TASK DURING PROD PERIOD

4.0 RELIABILITY PROGRAM TAILORING

Apart from cost considerations, comprehensive development of reliability program and task tailoring is beyond the scope of this guide. A recommendation is that a follow-on study be pursued in the area of reliability tailoring as a function of task effectiveness. The purpose of such a study would be to determine the various effectiveness relationships between program or system characteristics and task selection and implementation. Special emphasis would be placed on the cost driver tasks, tasks which are undergoing changes or are in development, and tasks which interface with other disciplines.

4.1 Time Phasing of Tailoring

Prior to the concept development phase, a system is known only to the extent that it must satisfy certain operational needs. The configuration, complexity and state-of-the-art developments are yet to be fully determined. However, at this point, the reliability manager or monitor is often called upon to begin the specification process for the reliability program. Two observations are pertinent here, and are listed below:

1) Th reliability task tailoring process is dynamic, continuing from concept development through validation, full-scale engineering development and production.

2) The contractor(s) should be fully involved in the tailoring process.

These two observations were developed from responses and follow-up interviews to the questionnaire discussed in the Overview of Section 2.0. A partial summary of the responses is provided in Table 4-1.

Answers to the first question regarding the phased timing of tailoring indicate a 36% positive response for "tailoring" during the concept development or contract definition phase. Other responses were 20% for tailoring to be included in the contractor(s) development and production proposal and 28% in favor of tailoring as a topic of negotiation at the time of contract award. Follow-up interviews brought out the need for additional considerations including that of contractor involvement in post award tailoring decisions.

TABLE 4-1 - QUESTIONNAIRE RESPONSE TO TAILORING DECISIONS

DURING WHAT PHASE SHOULD THE TAILORING PROCESS OCCUR?	RESPONSE	
	NO.	%
a. CONTRACT DEFINITION (STUDY TASK)	9	36
b. FSED/PROD. PROPOSAL (CONTR. RESPONSE)	5	20
c. CONTRACT AWARD (CUST./CONTR. NEGOT.)	7	28
d. OTHER	4	16
	25	

GIVEN THAT A TAILORING METHOD HAS BEEN DEVELOPED, HOW SHOULD IT BE MODIFIED IF THERE IS A SHORTAGE OF CONTRACT DOLLARS?	RESPONSE	
	NO.	%
a. PRO-RATA SCALING	1	4
b. DELETION OF SOME TASKS ON PRIORITY BASIS	11	41
c. CHANGES IN EXTENT OR COVERAGE OF TASKS	9	33
d. CHANGES IN DEPTH OF APPL. OF TASKS	5	18
e. OTHER	1	4
	27	

WHAT IN YOUR OPINION IS THE MOST SIGNIFICANT STUMBLING BLOCK TO IMPLEMENTING AN ACCEPTABLE RELIABILITY PROGRAM?	RESPONSE	
	NO.	%
a. PROGRAM FUNDS	7	37
b. CONTR./CUST. MANAG. BIAS OR APATHY	7	37
c. IMPROPER TAILORING	3	16
d. OTHER	2	10
	19	

The general lesson to be learned is that tailoring is not a "one-time" static process developed by the government reliability manager or monitor and imposed on a contractor, but a process which is dependent on information developed over time and which is dependent on a contractor's unique knowledge of the program and the system. Two examples will illustrate this point. On one program the requirement for a reliability oriented Failure Mode, Effects and Criticality Analysis (FMECA) was deleted because the results would have been, at best, marginal for this particular program. This decision was based on the configuration of the system, dominantly "single thread", which was not fully apparent at the time of specifying the FMECA task. Another example involves a program where a reliability "improvement" task was funded and implemented during the production phase and after the system had been introduced into operational service. The effectiveness of this particular task was based on the discovery and correction of deficiencies which could be exposed only as a result of operation in the military environment including that of the prevailing maintenance practices.

In both of the above examples, task cost effectiveness was the basic issue. In the one case, the task pay-off was less than the task cost and the savings were transferred to another task. In the other case, the additional expenditure on reliability improvement did

pay-off, resulting in a significant increase in system reliability. The latter case is an argument for advance commitment of funds to this type of product improvement effort.

The second question dealt with the problem of modifying reliability program efforts which had been well tailored to a particular program but which could not be supported with allocated contract funds. Here the problem was how to achieve the most effective program at a reduced cost. There was virtually no positive response to the idea of a scaling down of all tasks in proportion to the budget reduction. The most effective measures were thought to be either a deletion of some tasks on an effectiveness priority basis or a limitation on the coverage of tasks based on equipment criticality.

A final question concerned the respondents' opinions on the most significant stumbling block to implementing an acceptable reliability progam. While only 10% felt that improper tailoring was at fault, an equally divided response of 37% each felt the fault was with program funding limitations or bias or apathy on the part of the contractor or customer management.

4.2 Tailoring Mechanics

Development of an effective reliability program implies a tailoring of tasks which recognizes the unique features of a particular program or system. The tailoring process can involve more than a selection of tasks from MIL-STD-785 or -1543. It can involve development of new tasks or significant shaping in depth or extent of application of selected tasks. A prerequisite of effective tailoring, apart from the knowledge of program/task costs, is knowledge of the program/system and its various features which impact reliability.

For Air Force missile and space systems, reliability program tailoring basically involves the modification of the task provisions of MIL-STD-785 or MIL-STD-1543. These modifications are made to suit the nature and circumstances of a particular program/system. There are three primary modes of modification or tailoring:

- Selection of only those tasks which have "pay-off" for a given program/system (Select Category).
- Limiting application of tasks to those system components where there is "pay-off" (Extent Category).
- Controlling the depth of application to those levels where these is "pay-off" (Depth Category).

Additionally, tasks could be implemented or reported in some special manner, or a task not listed in -785 or -1543 could be added to suit the needs of a particular program. In the case of the former, options are often available on the particular way a task is implemented; e.g., the selection of a test plan from MIL-STD-781 or selection of a particular derating guide. For the latter case, it is sometimes advantageous to add tasks when it becomes apparent that by doing so a significant gain in reliability can be achieved; e.g., the addition of a reliability improvement task after the system's introduction into operational service.

Examples of the tailoring categories described above are as follows:

SELECT CATEGORY - A reliability oriented FMECA task is omitted because the system is a single thread (series) configuration at all levels and the effect of any failure is always loss of mission. This does not preclude performance of this type of analysis for maintainability or other non-reliability reasons.

EXTENT CATEGORY - A system component has been previously qualified for the same application and environment allowing this component to be exempt from certain task applications.

DEPTH CATEGORY - A system is in the Concept Development (C/D) Phase with definition lacking below the functional component level. Depth of analysis for this phase could be limited to "similar system" or MIL-HDBK-217 "Parts count Reliability Prediction" (Section 5.2) methods.

Realizing the ways reliability programs or tasks can be modified is the first step in the tailoring process. The second step is to determine the criteria for application of these various types of modifications. Here the concern is to determine what features or characteristics of a program or system have significant bearing on the choice and structuring of reliability tasks. These characteristics are basically the same as were investigated for cost except that the focus is changed. The cost investigation focused on how program/task costs vary as a function of these characteristics. The tailoring problem considers how the basic reliability program/task are modified as a function of these same characteristics. Together, the two investigations allow development of a reliability program which is both "tailored" to a given program/system and one which is sensitive to cost constraints; i.e., cost effective.

The basic characteristics discussed in the previous sections were developed by considering what type of reliability program modifications were likely to have an impact on program/task costs. Sources of these modifications stemmed from consideration of the following aspects of a system and its procurement program:

- SYSTEM EMPLOYMENT/DEPLOYMENT CHARACTERISTICS
  (Criticality of reliability to achievement of objectives, storage and service life requirements, maintenance concepts, etc.)

- MISSION CHARACTERISTICS
  (Mission duration, environments, duty cycles, numerical reliability requirement, etc.)

- SYSTEM CHARACTERISTICS
  (Hardware/software development status, complexity, configuration, etc.)

- PROGRAM CHARACTERISTICS
  (Schedule, unit costs, contractor role, phase, etc.)

Setting aside the cost considerations, the tailoring process concentrates on shaping a reliability program as influenced by these characteristics. Examples of these influences and their significance can be seen in the following discussions on program phase, system configuration and system deployment mode.

Table 4-2, taken from MIL-STD-785B, provides initial tailoring criteria in terms of program phase. The applicability of each reliability task is noted for each of four program phases. It further defines those special cases requiring considerable interpretation or reference to other military standards. These initial criteria do not, however, address the impact of other program/system characteristics on the tailoring process.

Program phase is a significant, if not the most significant, program characteristic. Phase impacts not only task selection, but also is a large factor in the required depth and extent of any selected task. For example, the FRACAS/FRB task is a considerably greater expenditure during the PROD phase than during either the VALID or FSED phases. Similarly, the FMECA task is approximately 8-10% of the reliability budget during FSED while falling to zero during the PROD phase. These large expenditure differences reflect the more basic differences in task application or modification as uncovered

TABLE 4-2 - TASK APPLICATION MATRIX

NO.	TASK TITLE	TYPE	PHASE CONC.	VALID	FSED	PROD
101	Reliability Program Plan	MGT	S	S	G	G
102	Monitor/Control Sub. & Suppl.	MGT	S	S	G	G
103	Program Reviews	MGT	S	S(2)	G(2)	G(2)
104	Failure Reporting Etc (FRACAS)	ENG	NA	S	G	G
105	Failure Review Board	MGT	NA	S(2)	G	G
201	Reliability Modeling	ENG	S	S(2)	G(2)	GC(2)
202	Reliability Allocations	ACC	S	G	G	GC
203	Reliability Predictions	ACC	S	S(2)	G(2)	GC(2)
204	Failure Modes, ETC (FMECA)	ENG	S	S(1,2)	G(1,2)	GC(1,2)
205	Sneak Circuit Analysis (SCA)	ENG	NA	NA	G(1)	GC(1)
206	Elec Parts/Circ Tol Anal	ENG	NA	NA	G	GC
207	Parts Program	ENG	S	S(2,3)	G(2)	G(2)
208	Reliability Critical Items	MGT	S(1)	S(1)	G	G
209	Effects of Funct Test Etc.	ENG	NA	S(1)	G	GC
301	Env. Stress Screen (ESS)	ENG	NA	S	G	G
302	Rel. Develop/Gwth Test	ENG	NA	S(2)	G(2)	NA
303	Rel. Qual Test	ACC	NA	S(2)	G(2)	G(2)
304	Prod Rel Accpt Test	ACC	NA	NA	S	G(2,3)

ACC
ENG - Reliability Engineering
MGT - Management
S - Selectively Applicable
G - Generally Applicable
GC - Generally Applicable to
to Design Changes Only

NA - Not Applicable
(1) - Requires Considerable Interpretation of Intent to be Cost Effective
(2) - MIL-STD-785 Not Primary Implem. Rqmt. Reference SOW or Other MIL-STDS

by consideration of the phase characteristics. The dynamics of the acquisition process, including the evolution of the design from concept to detail to hardware, has associated with it a "data availability" factor which greatly affects the depth of analysis oriented reliability tasks.

System configuration as it refers to whether a system is "single thread" (series), redundant or restorable, is another characteristic which can be significant to tailoring. The previous example, citing deletion of the reliability oriented FMECA for a single thread configuration, is but one case. Several of the other reliability tasks can also be affected. With redundant and restorable configurations, analyses tasks become more complex and must interface with other analyses of failure detection, maintainability, etc. Additionally, decisions on parts quality, derating, and testing can be affected by this characteristic. More generally, redundant or restorable configurations represent an exercise of a fundamental reliability improvement option with implications on the effectivity of other improvement options such as part quality or reliability growth testing.

As a final example, characteristics stemming from a system's deployment mode are considered. Many systems spend most of their

lifetimes in a so called "storage" mode. A requirement of such systems is to have a high readiness reliability; i.e., the system should have a high probability of being in an operable state when called upon for use. The implications of this requirement affect several reliability tasks. First, in the VALID phase there is an increased emphasis on analysis and development of data. Also during this phase, special test programs might be initiated to investigate long term reliability properties of parts and components. During all phases, interface analyses involving maintainability and logistics disciplines must be accomplished to assure compatibility with maintenance and logistics concepts. In general, as the reliability technology develops to more fully address this particular deployment mode, task modifications and additions can be expected.

The above examples addressed some tailoring implications stemming from consideration of three different program/system characteristics. There are many other considerations; however, these can be addressed in a similar manner by examining the implications of the characteristic on the reliability program and constituent tasks.

4.3 Tailoring Notes

The preceeding paragraphs discussed the general procedures and considerations necessary for tailoring of MIL-STD-785B reliability tasks to develop a cost-effective program. To supplement the general tailoring discussion, specific notes regarding task tailoring and system characteristic influences on task costs are presented in this section. These notes are a set of observations and "rules of thumb" accumulated during the data collection, screening, and analysis process.

As noted in Section 3.3, the cost statistics collected contained entries reflecting either explicit or implicit tailoring of reliability tasks. A careful screening of the data was necessary to develop a homogenous data set for analysis purposes. This screening process, together with the regression analyses, provided valuable insight into the tailoring process and its impact on reliability program costs.

This collection of notes is not intended to be a detailed treatment of reliability task cost tailoring. It is presented only to provide insight into the process and to document some historical reliability task cost tailoring decisions.

The data is structured by task; first displaying the task cost as a percentage of the reliability budget for each of the program categories (taken directly from the summary of Table 3-9), and followed with comments on the cost impact of any tailoring decision.

RELIABILITY PROGRAM PLAN

VALID	FSED	PROD	SMALL SPACE
3.2%	.1%	--	5.2%

The costs associated with the development of a reliability program plan are relatively small. Because the reliability program plan is a contractual document defining the remaining reliability effort, little tailoring is required for this task. It should also be noted that reliability program plans written to MIL-STD-785B appear (based on one sample) to be more costly than those written to MIL-STD-785A due to the additional detail required.

SUBCONTRACTOR CONTROL

VALID	FSED	PROD	SMALL SPACE
4.9%	3.6%	6.0%	8.7%

Subcontractor control is one of the nominal cost reliability tasks consuming some 4-6% of the total reliability budget. The primary functions of this task are to assure that the reliability requirements imposed upon subcontractors are supportive of the system requirements and to assure subcontactor performance and progress. Because of the basic nature of this task and its nominal costs, little historical tailoring activity was observed. It is not foreseen as a significant tailoring candidate for system or associate level contracts.

PROGRAM REVIEWS

VALID	FSED	PROD	SMALL SPACE
4.9%	1.7%	1.2%	23.3%

For major acquisition programs, program review is another of the nominal reliability program tasks comprising less than 5% of the reliability effort. As a result cost tailoring of this task is not considered significant.

In the raw data base, one entry relating to program reviews showed the effects of a non-typical application. A PROD program had large program review costs. This program included a major "technology

transfer" of a European missile design to U.S. production with an attendant increase in review and coordination efforts (approximately 10% of the total reliability effort).

For small space programs, program reviews were the major reliability program cost category. These programs can be typified as technology integration efforts as contrasted to technology development efforts. With this situation, high program review costs are not unexpected.

FRACAS & FRB

VALID	FSED	PROD	SMALL SPACE
16.4%	10.5%	17.7%	12.9%

The FRACAS and FRB activities were found to be major and consistent cost drivers for all program types and phases and, as such, present significant tailoring opportunity.

The historical task costs were found to be sensitive to actual hardware development and testing. One VALID program had minimal FRACAS and FRB costs due to lack of a test program in the basic effort. Thus, for tailoring and estimating of FRACAS and FRB costs, consideration must be given to the scope of test program.

The regression analysis found a direct correlation between FRACAS and FRB costs and the percentage of the failure rate subcontracted i.e., the higher the percentage subcontracted out, the less the FRACAS & FRB costs. This result was expected due to decreased contractor testing activity .

A final observation on tailoring FRACAS & FRB activities is that of cross-coupling with other reliability efforts. As noted above, a reduced test program results in reduced FRACAS and FRB costs. Also these two tasks categories, FRACAS/FRB and testing, can affect the analysis task. An example is a VALID effort designed to evaluate the trade, "demonstration flight tests vs expanded analyses,"as it relates to developing sufficient confidence in the missile design to proceed to FSED.

RELIABILITY ANALYSES

VALID	FSED	PROD	SMALL SPACE
16.7%	4.9%	10.6%	8.7%

Reliability analysis is one of the basic and cost consistent reliability tasks. The phase dependency demonstrated in the above table is confirmed by the correlation analyses. No tailoring activit , other than that accorded to phase, was observed in the

collected cost statistics. One opportunity for tailoring includes the trade of analyses vs test activities outlined previously.

FMECA

VALID	FSED	PROD	SMALL SPACE
4.8%	8.4%	--	1.4%

The FMECA task, although not an extreme cost driver, was one of the more heavily tailored tasks. As can be noted in the above percentage display, the FMECA task is phase dependent. During VALID, FMECA's are performed at the functional level in support of reliability modeling, and prediction analyses. During FSED, detailed, piece-part level FMECA's are the norm. Performance of FMECA's during PROD is considered of marginal value except as performed on hardware changes.

Two other system characteristics were found to affect the selection and extent of application of the FMECA task. During FSED and on programs involving the development of "single thread" systems, the FMECA task was often deleted for cost effectiveness reasons. It was also observed that programs involving integration of proven hardware

had little requirement for piece-part level FMECA's. Functional FMECA's with attendant reduced costs were more the norm for these types of programs.

SNEAK CIRCUIT ANALYSIS (SCA)

(Program Category %'s Not Applicable)

The sneak circuit analysis task was determined to be an expensive task and only selectively applied. In the survey data base it was applied to two VALID programs. On one program it represented 1.5% of the engineering budget (11.2% of the reliability budget) while on the second it was only a token effort with expenditure of only one manmonth. A partial FMECA was integrated with the former effort.

While the cost data was sparse on this task, the nature of the task in combination with its cost suggests tailoring in the form of selective application.

ELECTRONIC PARTS/CIRCUIT TOLERANCE ANALYSIS

VALID	FSED	PROD	SMALL SPACE
5.9%	3.1%	--	--

The circuit tolerance analysis task was well represented in the survey data base. It is an engineering oriented analysis task with minimum monitoring by the reliability function. Its application in the data base was uniform and no specific tailoring was observed.

PARTS PROGRAM

VALID	FSED	PROD	SMALL SPACE
8.7%	51%	34.3%	10.9%

Parts program costs were found to be significantly program and phase dependent. Costs ranged up to 51% of the total reliability program cost during FSED. Included in one program effort was the cost incurred to rescreen class "B" parts to class "S". This rescreening activity was not considered as a normal parts program activity. Because of its cost impact, the parts task is a prime candidate for tailoring. However, full treatment of the tailoring possibilities is beyond the scope of this study.

CRITICAL ITEMS

VALID	FSED	PROD	SMALL SPACE
2.2%	.1%	.1%	--

Little cost tailoring opportunity exists for this task. The primary tailoring observed in the data was a complete deletion of the task on several programs.

EFFECTS OF TEST, STORAGE ETC.

VALID	FSED	PROD	SMALL SPACE
6.0%	.7%	2%	--

There were seven data entries on this task including two from more recent VALID phase programs. The data indicates a trend towards increased emphasis on this task, especially on those systems whose exposure to failure during storage exeeds that of the operational mission. On the two more recent VALID phase programs where there was a "readiness" reliability requirement, the task cost averaged 10% of the reliability effort.

The regression equations confirmed the significance of this task in the presence of a readiness requirement. With a readiness requirement present, task cost is in the neighborhood of .25% of the engineering budget range. Without a readiness requirement, the task cost was negligible.

RELIABILITY TESTING

VALID	FSED	PROD	SMALL SPACE
10.1%	9.8%	9.8%	9.7%

The typical reliability testing task represents 10% of the reliability effort, independent of program type or phase. These costs reflect only those efforts charged directly to the reliability function. Included are charges for developing reliability test plans and procedures, for test monitoring and for test reporting. Costs associated with test performance, test hardware, technicians, etc. are charged against the engineering or manufacturing cost centers.

Opportunity for tailoring of the reliability test task are considerable. More recent programs indicate an increased emphasis on combined environment reliability testing (CERT) and environmental stress screening (ESS) with a reduced emphasis on formal demonstration.

APPENDIX A - DATA BASE

Quantitative information used in this study was developed from data collected from twelve separate space and/or missile programs. One of the programs yielded data for both an FSED and a PROD phase thus increasing the number of data sets to thirteen. The programs selected for inclusion in this study range in type from small space to large ICBM programs.

Table A-1 lists the programs by their types and gives the designator by which they will be referred to in this appendix.

Table A-2 lists the reliability tasks and the assigned reference numbers used throughout this appendix.

The raw program data is presented in Table A-3. This tables give the actual manmonth expenditures for the sample programs. Included in the table are engineering support (representing the effort contributed to the reliability program by other engineering disciplines) and engineering budget (representing the total engineering effort). As may be seen from the raw data base, the task expenditures for a program are highly dependent on the size of the program; that is, a program with a large engineering budget has

TABLE A-1 - PROGRAM DESIGNATIONS

PROGRAM DESIGNATION	PROGRAM PHASE	PROGRAM TYPE	PROGRAM DURATION (YEARS)
A	VALID	MISSILE/SPACE	5.5
B	VALID	SMALL MISSILE	2.5
C	VALID	MISSILE/TORPEDO	3.25
D	VALID	MISSILE/SPACE	4.0
E	FSED	AIR TO GROUND MISSILE	6.25
F	FSED	AIR TO GROUND MISSILE	2.25
G	FSED	LARGE SPACE	5.0
H	FSED	ICBM (GROUND SEGMENT)	5.0
I	PROD	AIR TO GROUND MISSILE	3.0
J	PROD	ICBM (FLIGHT SEGMENT)	4.0
K	PROD	GROUND TO AIR MISSILE (GROUND SEG)	3.25
L	PROD	SMALL SPACE	4.25
M	PROD	SMALL SPACE	2.5

TABLE A-2 - PROGRAM TASKS

TASK REFERENCE NO.	MIL-STD-785B TASK NO.	TASK DESCRIPTION
1	101	PROGRAM PLAN
2	102	MONITOR & CONTROL SUBCONTRACTOR
3	103	PROGRAM REVIEWS
4	104 & 105	FRACAS & FRB
5	201 - 203	ANALYSIS
6	204	FMECA
7	205	SNEAK CIRCUIT ANALYSIS (SCA)
8	206	ELEC. PARTS/CIRC. TOLERANCE ANAL.
9	207	PARTS
10	208	CRITICAL ITEMS
11	209	EFFECTS OF TEST, STORAGE, ETC.
12	301 - 304	TESTING
--	---	ENG. SUPPORT

TABLE A-3 - PROGRAM RELIABILITY TASK MANMONTH EXPENDITURES

	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL 1-12	ENG SUPPT	ENG BUDGET
A	0.0	3.0	0.0	6.0	12.5	24.0	1.0	0.0	2.0	0.0	1.0	8.0	57.5	11.1	2871
B	2.5	2.3	3.8	0.1	11.9	0.1	0.0	0.0	0.2	0.9	5.7	0.0	27.5	5.5	2130
C	4.7	5.9	4.8	21.2	15.0	5.2	0.0	0.0	21.0	2.1	7.8	13.0	100.7	15.9	4155
D	0.5	8.0	3.5	22.6	25.4	4.0	54.8	6.4	312.6	3.2	0.0	0.0	441.0	44.9	2871
E	2.0	107.7	116.8	281.3	123.7	123.3	0.0	65.6	233.7	0.0	26.3	232.4	1312.8	215.8	65646
F	1.7	26.6	7.0	97.9	43.6	0.0	0.0	56.3	387.2	0.0	15.9	85.9	722.1	50.2	17996
G	1.0	22.2	8.0	244.2	44.4	128.8	0.0	23.8	880.0	3.0	0.0	0.0	1355.4	95.1	29330
H	1.1	106.7	15.1	119.2	141.1	400.6	0.0	41.8	1211.1	2.0	0.0	7.8	2046.5	87.0	38078
I	0.0	14.1	2.1	100.4	59.8	0.0	0.0	0.0	231.5	0.0	20.4	58.9	487.2	174.3	12122
J	0.0	62.8	12.5	121.8	6.0	0.0	0.0	0.0	199.3	0.0	0.0	0.0	402.4	40.6	13824
K	0.0	23.9	34.0	60.4	42.5	0.0	0.0	0.0	107.2	1.9	8.6	35.5	314.0	54.6	8111
L	0.5	2.5	6.0	5.0	2.5	0 0.8	0.0	0.0	3.0	0.0	0.0	2.6	22.9	4.0	1341
M	0.6	1.5	4.5	1.5	1.5	0.0	0.0	0.0	2.0	0.0	0.0	1.8	13.4	4.3	1115

more dollars to spend for reliability than a program with a small engineering budget. For the purpose of comparison it is useful to compute the reliability expenditures as a percentage of the engineering budget, Table A-4.

A set of characteristics was developed which represent those features believed to produce the greatest influence on the allocation of time to do a given task. Table A-5 lists the scoring criteria for the characteristics and Table A-6 gives the scoring for each of the programs in the sample.

For the multiple regression analysis performed in Appendix B, a modified version of the data set presented in Table A-4 is used. The modified data set, Table A-7,uses a subset of the set of tasks and purposely leaves out those values which are considered to be nonrepresentative; that is, those values which were strongly influenced by factors outside of the characteristic set and which are atypical. Task 6 for Program A has been listed under FSED because it was performed on a piece part level which is not typical of a VALID program.

In Section 2.0 of the Overview, a set of averages was presented which was based on a manmonth per year level of effort. Table A-8

TABLE A-4 - RELIABILITY MANMONTH EXPENDITURE AS % OF ENGINEERING BUDGET

	1	2	3	4	5	6	7	8	9	10	11	12	ENG SUPPT	TOTAL
A	.0000	.1045	.0000	.2090	.4354	.8360	.0348	.0000	.0697	.0000	.0348	.2787	.3866	2.3895
B	.1174	.1080	.1784	.0047	.5587	.0047	.0000	.0000	.0094	.0423	.2676	.0000	.2564	1.5476
C	.1131	.1420	.1155	.5102	.3610	.1251	.0000	.0000	.5054	.0505	.1877	.3129	.3836	2.8070
D	.0134	.2143	.0937	.6053	.6803	.1071	1.4676	.1714	8.3719	.0857	.0000	.0000	1.2025	13.0132
E	.0030	.1641	.1779	.4285	.1884	.1878	.0000	.0999	.3560	.0000	.0401	.3540	.3287	2.3285
F	.0094	.1478	.0389	.5540	.2423	.0000	.0000	.3128	2.1516	.0000	.0884	.4773	.2789	4.0136
G	.0034	.0757	.0273	.8326	.1514	.4391	.0000	.0811	3.0003	.0102	.0000	.0000	.3242	3.2047
H	.0029	.2802	.0317	.3130	.3706	1.0521	.0000	.1098	3.1806	.0053	.0000	.0205	.2285	5.6032
I	.0000	.1163	.0173	.8282	.3803	.0000	.0000	.0000	1.9097	.0000	.1683	.4859	1.4379	5.3439
J	.0000	.4543	.0904	.8811	.0434	.0000	.0000	.0000	1.4417	.0000	.0000	.0000	.2938	3.2047
K	.0000	.2947	.4192	.7447	.5240	.0000	.0000	.0000	1.3217	.0234	.1060	.4377	.6732	4.5445
L	.0373	.1864	.4474	.3729	.1864	.0597	.0000	.0000	.2237	.0000	.0000	.1939	.2968	2.0045
M	.0538	.1346	.4037	.1346	.1346	.0000	.0000	.0000	.1794	.0000	.0000	.1615	.3857	1.5879

TABLE A-5 - CHARACTERISTIC SCORING CRITERIA

PROGRAM PHASE (I)	VALID FSED PROD	-1 0 1
PROGRAM PHASE (II)	VALID FSED PROD	-1 0 1
RELIABILITY CRITICALITY	COST EFFECTIVE BELOW NOMINAL NOMINAL ABOVE NOMINAL EXTREME	-1 -.5 0 .5 1
COMPLEXITY (PART COUNT)	4999 OR LESS 5000 - 9999 10000 - 19999 20000 - 49999 50000 - OR MORE	-2 -1 0 1 2
HARDWARE STATUS	OFF THE SHELF MODIFIED NEW	-1 0 1
NUMBER OF PART TYPES	999 OR LESS 1000 TO 1999 2000 TO 3999 4000 TO 7999 8000 OR MORE	-2 -1 0 1 2
MISSION REQ.	BELOW SOA NOMINAL DIFFICULT	-1 0 1
READINESS REQ.	YES THEY HAVE ONE NO THEY DON'T	1 0
PERCENTAGE OF FAILURE RATE SUBCONTRACTED	0% - 35% 35% - 65% 65% - 100%	-1 0 1
CONFIGURATION	SINGLE THREAD REDUNDANT RESTORABLE	-1 0 1

TABLE A-6 - PROGRAM VALUES FOR CHARACTERISTICS

	A	B	C	D	E	F	G	H	I	J	K	L	M
PROGRAM PHASE	-1	-1	-1	-1	0	0	0	0	1	1	1	1	1
RELIABILITY CRITICALITY	1	-1	0	-1	.5	-1	1	-1	-1	.5	0	1	1
COMPLEXITY	1	-2	-2	0	-1	0	1	2	0	1	2	0	-1
HARDWARE STATUS	-1	1	0	0	1	1	1	-1	1	0	0	0	0
NUMBER OF PART TYPES	2	-2	-2	0	-1	0	0	2	0	2	2	-1	-1
MISSION REQUIREMENT	0	0	0	0	0	0	1	1	0	0	1	0	0
READINESS REQUIREMENT	0	1	1	0	0	0	0	0	0	0	0	0	0
PERCENTAGE OF FAILURE RATE SUBCONTRACTED	1	0	1	0	1	1	-1	1	1	1	1	0	1
CONFIGURATION	-1	-1	-1	-1	-1	-1	0	1	-1	-1	-1	-1	-1

TABLE A-7 - MODIFIED DATA SET

		2	3	4	5	6	9	10	11	12
VALID	A	.1045	.0000	.2090	.4354	-----	.0697	.0000	.0348	.2787
	B	.1080	.1784	-----	.5587	-----	.0094	.0423	.2676	-----
	C	.1420	.1155	.5102	.3610	.1251	.5054	.0505	.1877	.3129
	D	.2143	.0937	.6053	.6803	.1071	-----	.0857	.0000	-----
FSED	A	-----	-----	-----	-----	.8360	-----	-----	-----	-----
	E	.1641	.1779	.4285	.1884	.1878	-----	.0000	.0401	.3540
	F	.1478	.0389	.5440	.2423	-----	2.1516	.0000	.0884	.4773
	G	.0757	.0273	.8326	.1514	.4391	3.003	.0102	.0000	-----
	H	.2802	.0397	.3130	.3706	1.0521	3.1806	.0053	.0000	-----
PROD	I	.1163	.0173	.8282	.3803	.0000	1.9097	.0000	.1683	.3129
	J	.4543	.0904	.8811	-----	.0000	1.4417	.0000	.0000	-----
	K	.2947	-----	.7447	.5240	.0000	1.3217	.0234	.1060	.4773
SMALL SPACE	L	.1864	.4474	.3729	.1864	.0597	.2234	.0000	.0000	.1615
	M	.1346	.4037	.1346	.1346	.0000	.1794	.0000	.0000	.1939

TABLE A-8 - MANMONTH PER YEAR EXPENDITURES

	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL 1-12	ENG SUPPT	ENG BUDGET
A	.00	.55	.00	1.09	2.27	4.36	.18	.00	.36	.00	.18	1.45	10.45	2.02	522.0
B	1.00	.92	1.52	.04	4.76	.04	.00	.00	.08	.36	2.28	.00	11.00	2.20	852.0
C	1.45	1.82	1.48	6.52	4.62	1.60	.00	.00	6.46	.65	2.40	4.00	30.98	1.89	1278.5
D	.13	2.00	.87	5.65	6.35	1.00	13.7	1.6	78.15	.80	.00	.00	110.25	11.23	933.5
E	.32	17.23	18.69	45.01	19.79	19.73	.00	10.50	37.39	.00	4.21	37.18	210.05	34.53	10503.4
F	.76	11.82	3.11	43.51	19.38	.00	.00	25.02	172.09	.00	7.07	38.18	320.93	22.31	7998.2
G	.20	4.44	1.60	48.84	8.88	25.76	.00	4.33	176.00	.60	.00	.00	271.08	19.02	5866.0
H	.22	21.34	3.02	23.84	28.22	80.12	.00	8.36	242.22	.40	.00	1.56	409.30	17.40	7615.6
I	.00	4.70	.70	33.47	19.93	.00	.00	.00	77.17	.00	6.80	19.63	162.40	58.10	4040.7
J	.00	15.70	3.13	30.45	1.50	.00	.00	.00	49.83	.00	.00	.00	100.60	10.15	3456.0
K	.00	7.35	10.46	18.58	13.08	.00	.00	.00	32.98	.58	2.65	10.92	96.62	16.80	2495.7
L	.12	.59	1.41	1.18	.59	.19	.00	.00	.71	.00	.00	.61	5.39	.94	315.5
M	.24	.60	1.80	.60	.60	.00	.00	.00	.80	.00	.00	.72	5.36	1.72	446.0

presents the program data in the manmonth per year form which was used to develop these averages. (The data in Table A-8 is simply the data in Table A-3 divided by the program durations listed in Table A-1)

ACHIEVED VERSUS PREDICTED RELIABILITY

The achieved reliability level for Programs A, L, and M are shown below in Table A-9. The reliability levels for Programs E, F, I, and J are classified; however, in each case the achieved levels were at or above requirements. The remaining programs are either in the development stage or are not yet in operational use, thus no data is available for these programs.

TABLE A-9 - PREDICTED VS MEASURED RELIABILITY

PROGRAM DESIGNATOR	PREDICTED RELIABILITY	MEASURED RELIABILITY	COMMENT
A	.90	1.00	6 FLIGHTS, 6 SUCCESSES
L	.87	1.00	3 FLIGHTS, 3 SUCCESSES
M	.97	.96	23 FLIGHTS, 22 SUCCESSES

APPENDIX B - ANALYSIS

In attempting to develop a cost estimation model which would, for a given set of program characteristics, give a rough estimate of the amount of effort to be expended doing a given reliability task, it is desirable to keep the model simple. The simplest model which would allow all or a selected subset of the characteristics to exert some influence on the cost is a multilinear model; that is,

$$\hat{y} = b_o + \sum_j x_j b_j \qquad \text{(B-1)}$$

where dependent variable, $\hat{y}$, denotes the cost estimate, and independent variables, x_j, denote the various characteristics involved. The b´s in equation are unknown at this stage.

For a set of sample programs, let the known program expenditures for a given reliability task be denoted by y_i. Similarly, let the characteristics which have bearing on this cost be denoted by x_{ij} where i refers to the program. The estimate of the cost for the i^{th} program is then given by:

$$\hat{y}_i = b_o + \sum_j x_{ij} b_j \qquad \text{(B-2)}$$

The difference between the actual and the estimated costs is given by:

$$\Delta y_i = y_i - \hat{y}_i = y_i - (b_o + \sum_j x_{ij} b_j) \qquad \text{(B-3)}$$

It becomes convenient at this point to set x_{ii} equal to 1 for all

values of i (since no characteristics have been assigned to an index as yet), and set b_o to zero. The form of the equation is not changed in that b_1 has replaced b_o in the role of the constant, but the equation may now be more easily expressed as:

$$\Delta y_i = y_i - \hat{y}_i = y_i - \sum_j x_{ij} b_j \ . \qquad \text{(B-4)}$$

A further compaction of notation takes place by recognizing this as a vector equation with Δy, y, $\hat{y}$, and b representing vectors and X representing a matrix. Equation B-4 may now be written as:

$$\Delta y = y - \hat{y} = y - Xb \qquad \text{(B-5)}$$

The best estimate of the cost then occurs when the length of the difference vector, that is the difference between the actual costs vector and the estimated costs vector, is at a minimum. Minimizing with respect to b and solving for b yields;

$$b = (X^T X)^{-1} X^T y, \qquad \text{(B-6)}$$

where T denotes the transpose and $^{-1}$ denotes the inverse. Solutions of this kind are called multiple linear regressions. For a regression to be meaningful, the size of the sample, n, must exceed the number of parameters, m, to be estimated; thus it is desirable to choose that set of independent variables (in this case characteristics) which minimize the unbiased standard error of estimate given by:

$$s = \sqrt{\Delta y . \Delta y / (n-m)} \ . \qquad \text{(B-7)}$$

The usual procedure is to use a stepwise regression routine. In

this procedure the independent variable yielding the smallest s is the first to be place in the equation. In the next step that independent variable which when coupled with the variable chosen in the first step yields the smallest s is chosen as the second variable to be included in the equation. This procedure continues until the standard error no longer continues to decrease. A problem with this procedure is that it doesn't necessarily yield the best solution since it does not consider all possible combinations of independent variables. For this study a computer program was developed which checks all possible combinations of up to three out of nine independent variables (counting the constant that means four estimated parameters).

The data used in this analysis is as presented in Appendix A in Tables A-6 and A-7 with the exception that configuration was left out and an attribute called phase II was added to account for a strong nonlinear influence due to program phase. A more rigorous investigation would use a phase-by-phase analysis of the data, but the number of programs in the data set was too small in this case to allow this.

Table B-1 presents the results of this investigation for those nine selected reliability tasks using one, two, and three independent

TABLE B-1 - RESULTS OF REGRESSION ANALYSIS

	b_1	PHASE (I)	PHASE (II)	CRITICALITY	COMPLEXITY	STATUS	PART TYPES	MISSION REQ.	READINESS	% F.R. SUBCONT	r	s
MONITOR & CONTROL SUBCON-TRACTOR	.18						.04				.54	.100
	.22	.08				-.07					.72	.087
	.25	.14				-.13	-.04				.76	.087
PROGRAM REVIEWS	.08				-.04						.74	.046
	.09		-.02		-.04						.75	.048
	.11	.04				-.04	-.05				.76	.051
FRACAS	.59	.19									.67	.183
	.71	.22								-.18	.83	.145
	.64	.22	.17							-.21	.91	.118
ANALYSIS	.24		.25								.78	.113
	.23		.24	-.07							.85	.100
	.26		.22	-.08		-.06					.89	.094
FMECA	.63		-.58								.79	.259
	.63		-.53			-.27					.95	.137
	.67		-.60	-.10		-.26					.97	.116
PARTS	2.78		-1.90								.81	.730
	2.78	.68	-1.90								.96	.397
	2.58	.63	-1.76					.29			.96	.407
CRITICAL ITEMS	.02	-.02									.57	.025
	.00	-.02	.02								.70	.022
	.00		.05		.03		-.04				.81	.020
EFFECTS OF TEST STORAGE, ETC.	.05								.18		.79	.060
	.04	.04							.22		.84	.056
	.00					.07	.04		.28		.90	.049
TESTING	.38			-.10							.89	.046
	.39	.05		-.07							.98	.022
	.37			-.07	.03	.05					1.00	.010

variables. The correlation coefficient, r, has been included as an indication of the closeness of fit.

From the table it can be seen that phase is the major contributor to variations in program task costs. However, the other items in the table are not all as intuition would lead one to believe. For example: it seems logical that the cost for analysis should increase with reliability criticality, yet the analysis shows a negative relationship. This, of course, could be due to changes in the engineering budget sensitive to the same characteristics which offset the changes in the reliability budget. Such masking of the data could be responsible for the inconclusive result or it may also be that there were insufficient data points or that the data itself was not reflective of the characteristics.

Other analysis methods were investigated and applied but produced no improvement over the linear regression methods discussed above.

APPENDIX C - RELIABILITY TASK DESCRIPTIONS

RELIABILITY TASK DESCRIPTIONS - CONDENSED FROM MIL-STD-785B

TASK SECTION 100 - PROGRAM SURVEILLANCE AND CONTROL

TASK	
101	RELIABILITY PROGRAM PLAN
102	MONITOR/CONTROL OF SUBCONTRACTORS AND SUPPLIERS
103	PROGRAM REVIEWS
104	FAILURE REPORTING, ANALYSIS, AND CORRECTION ACTION SYSTEM (FRACAS)
105	FAILURE REVIEW BOARD (FRB)

TASK SECTION 200 - DESIGN AND EVALUATION

TASK	
201	RELIABILITY MODELING
202	RELIABILITY ALLOCATIONS
203	RELIABILITY PREDICTIONS
204	FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)
205	SNEAK CIRCUIT ANALYSIS (SCA)
206	ELECTRONIC PARTS/CIRCUITS TOLERANCE ANALYSIS
207	PARTS PROGRAM
208	RELIABILITY CRITICAL ITEMS
209	EFFECTS OF FUNCTIONAL TESTING, STORAGE, HANDLING, PACKAGING, TRANSPORTATION, AND MAINTENANCE

TASK SECTION 300 - DEVELOPMENT AND PRODUCTION TESTING

TASK	
301	ENVIRONMENTAL STRESS SCREENING (ESS)
302	RELIABILITY DEVELOPMENT/GROWTH TEST (RDGT) PROGRAM
303	RELIABILITY QUALIFICATION TEST (RQT) PROGRAM
304	PRODUCTION RELIABILITY ACCEPTANCE TEST (PRAT) PROGRAM

TASK 101

RELIABILITY PROGRAM PLAN

101.1 PURPOSE. The purpose of Task 101 is to develop a reliability program plan which identifies and ties together all program management tasks required to accomplish program requirements.

101.2 TASK DESCRIPTION.

101.2.1 A reliability program plan shall be prepared and shall include, but not be limited to, the following:

a. A description of how the reliability program will be conducted to meet the requirements of the SOW.

b. A detailed description of how each specified reliability accounting and engineering design task(s) will be performed or complied with.

c. The procedures (wherever existing procedures are applicable) to evaluate the status and control of each task, and identification of the organization unit with the authority and responsibility for executing each task.

d. Description of interrelationships of reliability tasks and activities and description of how reliability tasks will interface with other system

oriented tasks. The description shall specifically include the procedures to be employed which assure that applicable reliability data derived from, and traceable to, the reliability tasks specified are integrated into the LSAP and reported on appropriate LSAR.

e. A schedule with estimated start and completion points for each reliability program activity or task.

f. The identification of known reliability problems to be solved, an assessment of the impact of these problems on meeting specified requirements, and the proposed solutions or the proposed plan to solve these problems.

g. The procedures or methods (if procedures do not exist) for recording the status of actions to resolve problems.

h. The designation of reliability milestones (includes design and test).

i. The method by which the reliability requirements are disseminated to designers and associated personnel.

j. Identification of key personnel for managing the reliability program.

k. Description of the management structure, including

interrelationship between line, service, staff, and policy organizations.

l. Statement of what source of reliability design guidelines or reliability design review checklist will be utilized.

m. Description of how reliability contributes to the total design, and the level of authority and constraints on this engineering discipline.

n. Identification of inputs that the contractor needs from operation and support experience with a predecessor item or items. Inputs should include measured basic reliability and mission reliability values, measured environmental stresses, typical failure modes, and critical failure modes.

101.2.2 The contractor may propose additional tasks or modifications with supporting rationale for such additions or modifications.

101.2.3 When approved by the procuring activity and if incorporated into the contract, the reliability program plan shall become, together with the SOW, the basis for contractual compliance.

TASK 102

MONITOR/CONTROL OF SUBCONTRACTORS AND SUPPLIERS

102.1 PURPOSE. The purpose of Task 102 is to provide the prime contractor and PA with appropriate surveillance and management control of subcontractors/suppliers reliability programs so that timely management action can be taken as the need arises and program progress is ascertained.

102.2 TASK DESCRIPTION

102.2.1 The contractor shall insure that system elements obtained from suppliers will meet reliability requirements. This effort shall apply to CFE items obtained from any supplier whether in the first or any subsequent tier, or whether the item is obtained by an intra-company order from any element of the contractor's organization. All subcontracts shall include provisions for review and evaluation of the suppliers' reliability efforts by the prime contractor, and by the procuring activity at their discretion.

102.2.2 The contractor shall assure, and advise the PA, that his subcontractor' and suppliers' reliability efforts are consistent with overall system requirements, and that

provisions are made for surveillance of their reliability activities. The contractor shall, as appropriate:

a. Incorporate quantitative reliability requirements in subcontracted equipment specifications.

b. Assure that subcontractors have a reliability program that is compatible with the overall program and includes provisions to review and evaluate their supplier(s) reliability efforts.

c. Attend and participate in subcontractors' design reviews.

d. Review subcontractors' predictions and analyses for accuracy and correctness of approach.

e. Furnish subcontractors with data from testing or usage of their product when testing and usage are outside their control.

f. Review subcontractors' test plans, procedures, and reports for correctness of approach and test details.

g. Review subcontractors' progress reports.

h. Assure that subcontractors have, and are pursuing, a vigorous corrective action effort to eliminate causes of unreliability.

i. Reserve for himself and for the PA the right to send

personnel into the subcontractors' facilities as necessary to monitor and evaluate the subcontractors' reliability programs and related activities.

j. Assure that subcontractors/suppliers will provide him with the necessary technical and administrative support for the items they supply during production and deployment of the hardware. This support may include failure analyses and corrective action for failures occurring in the total use environment, if specified under 102.2 herein.

k. Ensure that selected items (critical items, et cetera) obtained from suppliers are covered by specifications, drawings, and other technical documents and that the requirements called out adequately control those parameters and characteristics that may affect reliability of the end item.

l. Unless otherwise specified by the PA, conduct or control his subcontractors/suppliers reliability demonstration (qualification and acceptance) tests on behalf of the government to provide a defensible basis for determining the supplier's contractual compliance with quantitative reliability requirement.

TASK 103

PROGRAM REVIEWS

103.1 PURPOSE. The purpose of Task 103 is to establish a requirement for the prime (or associate) contractor to conduct reliability program reviews at specified points in time to assure that the reliability program is proceeding in accordance with the contractual milestones and that the weapon system, subsystem, equipment, or component quantitative reliability requirements will be achieved.

103.2 TASK DESCRIPTION

103.2.1 The reliability program shall be planned and scheduled to permit the contractor and the PA to review program status. Formal review and assessment of contract reliability requirements shall be conducted at major program points, identified as system program reviews, as specified by the contract. As the program develops, reliability progress shall also be assessed by the use of additional reliability program reviews as necessary. The contractor shall schedule reviews as appropriate with his subcontractors and suppliers and insure that the PA is informed in advance of each review.

103.2.2 The reviews shall identify and discuss all pertinent aspects of the reliability program such as the following, when applicable:

a. AT THE PRELIMINARY DESIGN REVIEW (PDR):

(1) Updated reliability status including:

(a) Reliability modeling

(b) Reliability apportionment

(c) Reliability predictions

(d) FMECA

(e) Reliability content of specification

(f) Design guideline criteria

(g) Other tasks as identified

(2) Other problems affecting reliability

(3) Parts program progress

(4) Reliability critical items program

b. AT THE CRITICAL DESIGN REVIEW (CDR):

(1) Reliability content of specifications

(2) Reliability prediction and analyses

(3) Parts program status

(4) Reliability critical items program

(5) Other problems affecting reliability

(6) FMECA

(7) Identification of circuit reference designators whose stress levels exceed the recommended parts application criteria.

(8) Other tasks as identified

c. AT RELIABILITY PROGRAM REVIEWS:

(1) Discussion of those items reviewed at PDRs and CDRs

(2) Results of failure analyses

(3) Test schedule: start dates and completion dates

(4) Parts, design, reliability, and schedule problems

(5) Status of assigned action items

(6) Contractor assessment of reliability task effectiveness

(7) Other topics and issues as deemed appropriate by the contractor and the PA

d. AT THE TEST READINESS REVIEW:

(1) Reliability analyses status, primary prediction

(2) Test schedule

(3) Test profile

(4) Test plan including failure definition

(5) Test report format

(6) FRACAS implementation

e. AT THE PRODUCTION READINESS REVIEW:

(1) Results of applicable RQT's

(2) Results of applicable reliability/growth testing

TASK 104

FAILURE REPORTING, ANALYSIS, AND CORRECTIVE ACTION SYSTEM (FRACAS)

104.1 PURPOSE. The purpose of Task 104 is to establish a closed loop failure reporting system, procedures for analysis of failures to determine cause, and documentation for recording corrective action taken.

104.2 TASK DESCRIPTION

104.2.1 The contractor shall have a closed loop system that collects, analyzes, and records failures that occur for specified levels of assembly prior to acceptance of the hardware by the procuring activity. The contractor's existing data collection, analysis and corrective action system shall be utilized, with modification only as necessary to meet the requirements specified by the PA.

104.2.2 Procedures for initiating failure reports, the analysis of failures, feedback of corrective action into the design, manufacturing and test processes shall be identified. Flow diagram(s) depicting failed hardware and data flow shall also be documented. The analysis of failures shall establish and categorize the cause of failure.

104.2.3 The closed loop system shall include provisions to assure that effective corrective actions are taken on a timely basis by a follow-up audit that reviews all open failure reports, failure analyses, and corrective action suspense dates, and the reporting of delinquencies to management. The failure cause for each failure shall be clearly stated.

104.2.4 When applicable, the method of establishing and recording operating time, or cycles, on equipments shall be clearly defined.

104.2.5 The contractor's closed loop failure reporting system data shall be transcribed to Government forms only if specifically required by the procuring activity.

TASK 105

FAILURE REVIEW BOARD (FRB)

105.1 PURPOSE. The purpose of Task 105 is to require the establishment of a failure review board to review failure trends, significant failures, corrective actions status, and to assure that adequate corrective actions are taken in a timely manner and recorded during the development and production phases of the program.

105.2 TASK DESCRIPTION

105.2.1 The FRB shall review functional/performance failure data from appropriate inspections and testing including subcontractor qualification, reliability, and acceptance test failures. All failure occurrence information shall be available to the FRB. Data including a description of test conditions at time of failure, symptoms of failure, failure isolation procedures, and known or suspected causes of failure shall be examined by the FRB. Open FRB items shall be followed up until failure mechanisms have been satisfactorily identified and corrective action initiated. The FRB shall also maintain and disseminate the status of corrective action implementation and

effectiveness. Minutes of FRB activity shall be recorded and kept on file for examination by the examination by the procuring activity during the term of the contract. Contractor FRB members shall include appropriate representatives from design, reliability, system safety, maintainability, manufacturing, and parts and quality assurance activities. The procuring activity reserves the right to appoint a representative to the FRB as an observer. If the contractor can identify and utilize an already existing and operating function for this task, then he shall describe in his proposal how that function will be employed to meet the procuring activity requirements. This task shall be coordinated with Quality Assurance organizations to insure there is no duplication of effort.

TASK 201

RELIABILITY MODELING

201.1 PURPOSE. The purpose of Task 201 is to develop a reliability model for making numerical apportionments and estimates to evaluate system/subsystem/equipment reliability.

201.2 TASK DESCRIPTION

201.2.1 A reliability mathematical model based on system/subsystem/equipment functions shall be developed and maintained. As the design evolves, a reliability block diagram shall be developed and maintained for the system/subsystem with associated allocations and predictions for all items in each reliability block. The reliability block diagram shall be keyed and traceable to the functional block diagram, schematics, and drawings, and shall provide the basis for accurate mathematical representation of reliability. Nomenclature of items used in reliability block diagrams shall be consistent with that used in functional block diagrams, drawings, and schematics, weight statements, power budgets, and specifications. The model outputs shall be expressed in terms of

contractual reliability requirements and other reliability terms as specified. When required for the PROD phase, the model shall be updated to include hardware design changes.

201.2.2 The reliability mathematical model shall be updated with information resulting from reliability and other relevant tests as well as changes in item configuration, mission parameters and operational constraints. Inputs and outputs of the reliability mathematical model shall be compatible with the input and output requirements of the system and subsystem level analysis models.

201.2.3 Modeling techniques shall provide separate outputs for: (1) basic reliability, and (2) mission reliability, of the system/sub-system/equipment. A single series calculation of basic reliability, and the modeling techniques described in Appendix A of MIL-HDBK-217 for mission reliability, shall be used unless otherwise specified.

TASK 202

RELIABILITY ALLOCATIONS

202.1 PURPOSE. The purpose of Task 202 is to assure that once quantitative system requirements have been determined, they are allocated or apportioned to lower levels.

202.2 TASK DESCRIPTION

202.2.1 Both basic reliability and mission reliability requirements shall be allocated to the level specified and shall be used to establish baseline requirements for designers. Requirements consistent with the allocations shall be imposed on the subcontractors and suppliers. The apportioned values shall be included in appropriate sections of procurement specifications, critical item specifications, and contract end item specifications. All allocated reliability values established by the contractor and included in contract end item specifications shall be consistent with the reliability model (see Task 201) and any change thereto, and subject to procuring activity review.

TASK 203

RELIABILITY PREDICTIONS

203.1 PURPOSE. The purpose of Task 203 is to estimate the basic reliability and mission reliability of the system/subsystem/equipment and to make a determination of whether those reliability requirements can be achieved with the proposed design.

203.2 TASK DESCRIPTION

203.2.1 Reliability predictions shall be made for the system, subsystem/equipment. When required, predictions shall account for, and differentiate between, each mode of item operation as defined in the item specification. Predictions shall be made showing: (1) basic reliability of the item during the life profile specified by the PA, to provide a basis for life cycle cost and logistics support analysis; and (2) mission reliability of the item during the mission profile(s) specified by the PA, to provide a basis for analysis of item operational effectiveness. These predictions shall be made using the associated reliability block diagram and failure rate data approved by, or provided by, the procuring activity. Items shall not be

excluded from the MCSP or other mission reliability predictions unless substantiating documentation (such as FMECA) verify that the item failure has no influence on the required measure of mission reliability. Prior to such exclusions from the predictions, an assessment and approval shall be obtained from the procuring activity.

203.2.1.1 Failure rates other than those established at contract award may be used only upon approval of the procuring activity.

203.2.1.2 The permissible failure rate adjustment factors for standby operation and storage shall be as specifically agreed to by the procuring activity.

203.2.1.3 When the individual part operating conditions are defined, the prediction procedure in Section 2 of MIL-HDBK-217, or PA approved alternative, shall be used.

203.2.2 Predictions for electronic equipment shall be made using one of the two methods contained in MIL-HDBK-217, or alternatives approved or provided by the PA. Predictions for mechanical, electrical, and electro-mechanical equipment shall be made using either contractor data or alternatives, both of which shall require PA approval.

TASK 204

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

204.1 PURPOSE. The purpose of Task 204 is to identify potential design weaknesses through systematic, documented consideration of the following: all likely ways in which a component or equipment can fail; causes for each mode; and the effects of each failure (which may be different for each mission phase).

204.2 TASK DESCRIPTION

204.2.1 FMECA shall be performed to the level specified (subsystem, equipment, functional circuit, module, or piece part level). All failure modes shall be postulated at that level and the effects on all higher levels shall be determined. The FMECA shall consider failure mode, failure effect and criticality (impact on safety, readiness, mission success, and demand for maintenance/logistics support), and the failure indication to the operator and maintenance personnel by life/mission profile phase. This analysis shall be scheduled and completed concurrently with the design effort so that the design will reflect analysis conclusions and recommendations. The results and

current status of FMECA shall be used as inputs to design trade-offs, safety engineering, maintenance engineering, maintainability, logistic support analysis, test equipment design and test planning activities, et cetera.

204.2.2 A sample FMECA worksheet format shall be submitted to the PA for approval and details such as who (by discipline) shall perform the analysis, who shall review it for adequancy and accuracy, when and how it shall be updated, and what specific uses shall be made of the results (e.g., identifying potential system weaknesses, as a tool for evaluating the effectiveness of built-in test, updating reliability assessments, updating critical item control procedures, development of safety, maintainability, and human engineering design and operational criteria, et cetra) shall be identified.

TASK 205

SNEAK CIRCUIT ANALYSIS (SCA)

205.1 PURPOSE. The purpose of Task 205 is to identify latent paths which cause occurrence of unwanted functions or inhibit desired functions, assuming all components are functioning properly.

205.2 TASK DESCRIPTION

205.2.1 Sneak circuit analyses of critical circuitry shall be conducted to identify latent paths which cause unwanted functions to occur or which inhibit desired functions. In making these analyses, all components shall be assumed to be functioning properly. These analyses shall be made using production manufacturing documentation for each circuit analyzed.

205.2.2 A list of those functions/circuits to be analyzed, and the priorities given each subassembly in the analysis, shall be percented for AP approval at CDR, together with the supporting rationale for the selections made. Results of the analyses and actions taken as a result of analyses findings shall be made available to the procuring activity upon request.

TASK 206

ELECTRONIC PARTS/CIRCUITS TOLERANCE ANALYSIS

206.1 PURPOSE. The purpose of Task 206 is to examine the effects of parts/circuits electrical tolerances and parasitic parameters over the range of specified operating temperatures.

206.2 TASK DESCRIPTION

206.2.1 Parts/circuits tolerance analyses shall be conducted on critical circuitry as defined in the contract. These analyses shall verify that, given reasonable combinations of within-specification characteristics and parts tolerance buildup, the circuitry being analyzed will perform within specification performance. In making these analyses the contractor shall examine the effect of component parasitic parameters, input signal and power tolerances, and impedance tolerances on electrical parameters, both at circuit nodes (component interconnections) and at input and output points. Since all of the stated factors may not be significant to all circuits, only the critical facto s for that circuit shall be considered.

206.2.2 Component characteristics, (life-drift and temperature) shall be factored into the analyses. These characteristics or values shall include resistance, capacitance, transistor gain, relay opening or closing time, et cetera.

206.2.3 The inductance of wire-wound resistors, parasitic capacitance, and any other similar phenomena shall be taken into account, where appropriate. Maximum variations in input signal or power supply voltage, frequency, bandwidth, impedance, phase, et cetera shall be used in the analyses. The impedance characteristics of the load shall be considered as well. Circuit node parameters (including voltage, current, phase, and waveform), circuit element rise time, timing of sequential events, circuit power dissipation, and circuit-load impedance matching under worst case conditions shall also be considered. These parameters shall be analyzed for their effect on the performance of circuit components.

206.2.4 A list of those functions/circuits to be analyzed shall be presented at PDR. The most infavorable combination of realizable conditions to be considered in the parts/circuits tolerance analyses shall be defined for

approval by the procuring activity. Results of the analyses and actions taken as a result of analyses findings shall be made available to the procuring activity upon request.

TASK 207

PARTS PROGRAM

207.1 PURPOSE. The purpose of Task 207 is to control the selection and use of standard and nonstandard parts.

207.2 TASK DESCRIPTION

207.2.1 A parts control program shall be established in accordance with MIL-STD-965 procedures, as designated in the contract.

207.2.2 Reliability design guidelines shall be developed and documented to include derating criteria, junction temperatures, and parts application criteria. Safety margins for nonelectronic parts will also be included when appropriate. The guidelines shall be consistent with guidance provided by the PA.

TASK 208

RELIABILITY CRITICAL ITEMS

208.1 PURPOSE. The purpose of Task 208 is to identify and control these items which require "special attention" because of complexity, application of advanced state-of-the-art techniques, and the impact of potential failure on safety, readiness, mission success, and demand for maintenance/logistics support.

208.2 TASK DESCRIPTION

208.2.1 Reliability critical items shall be identified by FMECA or other methods and shall be controlled. Methods and procedures for control and testing of the reliability critical items shall be identified along with justification(s) for decontrolling the item if that is intended. When specified, the procedures shall include engineering support of critical items during FSED government field testing, which shall include provisions for confirming failures which may occur, expediting failure cause determination, and determining and incorporating, or verifying, the necessary corrective action.

TASK 209

EFFECTS OF FUNCTIONAL TESTING, STORAGE, HANDLING, PACKAGING, TRANSPORTATION, AND MAINTENANCE

209.1 PURPOSE. The purpose of Task 209 is to determine the effects of storage, handling, packaging, transportation, maintenance, and repeated exposure to functional testing on hardware reliability.

209.2 TASK DESCRIPTION

209.2.1 Procedures shall be established, maintained, and implemented to determine by test and analysis, or estimation, the effects of storage, handling, packaging, transportation, maintenance, and repeated exposure to functional testing on the design and reliability of the hardware. The results of this effort shall include items such as:

a. Identification of equipments and their major or critical characteristics which deteriorate with storage age or environmental conditions (including shock and vibration, et cetera).

b. Identification of procedures for periodic field inspection or tests (including recall for test) or stockpile reliability evaluation. The procedures shall include suggested quantity of items for test and acceptable levels of performance for parameters under test.

c. Identification of special procedures for maintenance or restoration.

The results of this effort shall be used to support long term failure rate predictions, design trade-offs, definition of allowable test exposures, retest after storage decisions, packaging, handling, or storage requirements, and refurbishment plans.

TASK 301

ENVIRONMENTAL STRESS SCREENING (ESS)

301.1 PURPOSE. The purpose of Task 301 is to establish and implement environmental stress screening procedures so that early failure(s) due to weak parts, workmanship defects, and other non-conformance anomolies can be identified and removed from the equipment.

301.2 TASK DESCRIPTION

301.2.1 Environmental stress screening (also known as pre-conditioning, burn-in, et cetera) shall be conducted on parts, subassemblies, and complete units for both developmental and production items.

301.2.1.1 During development, ESS test procedures, taking into consideration the equipment design, part/component technology, and production fabrication techniques, shall be formulated. ESS procedures shall be designed for the end item and for all lower level items which will be procured separately as spare or repair parts. A plan for implementing these procedures shall also be prepared, indicating the proposed application of ESS during development and production. The proposed ESS

procedures and implementation plan shall be subject to approval by the PA.

301.2.2 ESS testing shall be designed to stimulate relevant failures by stressing the item. The stressing need not simulate the precise operational environment the item will see. Environmental stress types may be applied in sequence. During ESS, the item shall be cycled through its operational modes while simultaneously being subjected to the required environmental stresses.

301.2.3 Upon approval of the proposed ESS procedures and implementation plan, a detailed environmental stress screening test plan shall be prepared and included as part of the reliability test plan. The ESS detailed test plan shall include the following, subject to PA approval prior to initiation of testing:

a. Description of environmental stress types, levels, profiles, and exposure times to be applied.

b. Identification of level (board, sub-assembly, assembly) at which testing will be accomplished.

c. Identification of item performance and stress parameters to be monitored during ESS.

d. Proposed test duration (failure-free interval and maximum ESS test time per item).

301.2.4 The results of ESS testing during development shall be analyzed and used as the basis for the ESS procedures to be specified for production.

TASK 302

RELIABILITY DEVELOPMENT/GROWTH TEST (RDGT) PROGRAM

302.1 PURPOSE. The purpose of Task 302 is to conduct prequalification testing (also known as TAAF) to provide a basis for resolving the majority of reliability problems early in the development phase, and incorporating corrective action to preclude recurrence, prior to the start of production.

302.2 TASK DESCRIPTION

302.2.1 A reliability development/growth test (TAAF test) shall be conducted for the purpose of enhancing system reliability through the identification, analysis, and correction of failures and the verification of the corrective action effectiveness. Mere repair of the test item does not constitute corrective action.

302.2.1.1 To enhance mission reliability, corrective action shall be focused on mission-critical failure modes. To enhance basic reliability, corrective action shall be focused on the most frequent failure modes regardless of their mission criticality. These efforts shall be balanced to meet predicted growth for both parameters.

302.2.1.2 Growth testing will emphasize performance monitoring,

failure detection, failure analysis, and the incorporation and verification of design corrections to prevent recurrence of failures.

302.2.2 A TAAF test plan shall be prepared and shall include the following subject to PA approval prior to initiating of testing:

a. Test objectives and requirements, including the selected growth model and growth rate and the rationale for both selections.

b. Identification of the equipment to be tested and the number of test items of each equipment.

c. Test conditions, environmental, operational and performance profiles, and the duty cycle.

d. Test schedules expressed in calendar time and item life units, including the test milestones and test program review schedule.

e. Test ground rules, chargeability criteria and interface boundaries.

f. Test facility and equipment descriptions and requirements.

g. Procedures and timing for corrective actions.

h. Blocks of time and resources designated for the incorporation of design corrections.

i. Data collection and recording requirements.

j. FRACAS.

k. Government furnished property requirements.

l. Description of preventive maintenance to be accomplished during test.

m. Final disposition of test items.

n. Any other relevant considerations.

302.2.3 As specified by the procuring activity, the TAAF test plan shall be submitted to the procuring activity for its review and approval. This plan, as approved, shall be incorporated into the contract and shall become the basis for contractual compliance.

TASK 303

RELIABILITY QUALIFICATION TEST (RQT) PROGRAM

303.1 PURPOSE. The purpose of Task 303 is to determine that the specified reliability requirement have been achieved.

303.2 TASK DESCRIPTION

303.2.1 Reliability qualification tests shall be conducted on equipments which shall be identified by the PA and which shall be respresentative of the approval production configuration. The reliability qualification testing may be integrated with the overall system/equipment qualification testing, when practicable, for cost-effectiveness; the RQT plan shall so indicate in this case. The PA shall retain the right to disapprove the test failure relevancy and chargeability determinations for the reliability demonstrations.

303.2.2 A RQT plan shall be prepared in accordance with the requirements of MIL-STD-781, or alternative approved by the PA, and shall include the following, subject to PA approval prior to initiation of testing:

a. Test objectives and selection rationale.

b. Identification of the equipment to be tested (with identification of the computer programs to be used for the test, if applicable) and the number of test items of each equipment.

c. Test duration and the appropriate test plan and test environments. The test plan and test environments (if life/mission profiles are not specified by the PA) shall be derived from MIL-STD-781. If it is deemed that alternative procedures are more appropriate, prior PA approval shall be requested with sufficient selection rationale to permit procuring activity evaluation.

d. A test schedule that is reasonable and feasible, permits testing of equipment which are representative of the approved production configuration, and allows sufficient time, as specified in the contract, for PA review and approval of each test procedure and test setup.

303.2.3 Detailed test procedures shall be prepared for the tests that are included in the RQT plan.

303.2.4 As specified by the procuring activity, the RQT plan and test procedures shall be submitted to the procuring activity for its review and approval. These documents, as approved, shall be incorporated into the contract and shall become the basis for contractual compliance.

TASK 304

PRODUCTION RELIABILITY ACCEPTANCE TEST (PRAT) PROGRAM

304.1 PURPOSE. The purpose of Task 304 is to assure that the reliability of the hardware is not degraded as the result of changes in tooling, processes, work flow, design, parts quality, or other characteristics identified by the PA.

304.2 TASK DESCRIPTION

304.2.1 Production reliability acceptance testing shall be conducted on production equipments which shall be identified by the procuring activity.

304.2.2 A PRAT plan shall be prepared in accordance with the requirements of MIL-STD-781, or alternative approved by the PA, and shall include the following, subject to PA approval prior to initiation of testing:

a. Test objectives and selection rationale.

b. Identification of the equipment to be tested and the number of test samples of each equipment.

c. Test duration, test frequency, and the appropriate test plan and test environments. The test plan and test environments (if mission profiles are not specified by the PA) shall be derived from

MIL-STD-781. If it is deemed that alternative procedures are more appropriate, prior PA approval shall be requested with sufficient selection rationale to permit procuring activity evaluation.

d. A test schedule that is reasonable and feasible, and in consonance with the production delivery schedule.

304.2.3 Detailed test procedures shall be prepared for the tests that are included in the PRAT plan or the equipment specification.

304.2.4 As specified by the procuring activity, the PRAT plan and procedures shall be submitted to the procuring activity for its review and approval. These documents, as approved by the procuring activity, shall be incorporated into the contract and shall become the basis for contractual compliance.

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